Wm DeW. Hyde

VOCATIONS

SETTING FORTH THE VARIOUS PHASES OF THE MECHANIC ARTS, HOME-MAKING, FARMING AND WOODCRAFT, BUSINESS, THE PROFESSIONS OF LAW, MINISTRY AND MEDICINE, PUBLIC SERVICE, LITERATURE AND JOURNALISM, TEACHING, MUSIC, PUBLIC ENTERTAINMENT AND THE FINE ARTS .·. WITH PRACTICAL INTRODUCTIONS BY A CORPS OF ASSOCIATE EDITORS

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VOCATIONS, in Ten Volumes
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FOREWORD TO PARENTS

BY

WILLIAM DEWITT HYDE, LL.D.

WHEN Benjamin Franklin was old enough to choose a vocation his father took him around to see all the trades then found in Boston; with the result that the boy decided to be a printer. The world, however, is too large, and industry too complicated, to permit the father to do that to-day. At the meeting of the National Education Association in Boston in July, 1910, President Eliot said that the Life Career Motive, whether in school, or college, or life, is the motive under which we all do our best work. To bring the vocations home to the boys and girls, and help them to find this life career motive early, is the aim of these books.

Parents, teachers, and psychologists unite in regarding the period of adolescence as the most critical period in the child's life. Then he becomes a problem to his father; a grief to his mother; an annoyance to his teacher; even a burden to himself. For unhappy as he makes others in his obstreperous efforts to cut the leading strings of parental and scholastic authority, he is still more unhappy and unsettled himself. Yet all this ferment and storm and stress is normal, wholesome, and beneficent. It marks the transition from childhood to manhood and womanhood. There is no occasion for the father to worry, or the mother to grieve, or the teacher to despair. There is however a splendid opportunity to

guide this expanding eagerness and energy into channels of lifelong usefulness and happiness.

The church, the Christian Association, the school, and intelligent parents are waking up to the fact that one of the chief solutions of this problem presented at adolescence is to be found in wisely guided interest in the youth's future vocation. The one matter of supreme interest to this otherwise obstreperous boy or giddy girl is what they are going to do in life. Touch that chord tactfully, intelligently, helpfully, and you are sure of genuine and eager response.

The Boston Young Men's Christian Association has established a Vocation Bureau for the advice of young men in choosing or changing occupations. In connection with it is a school for Vocation Counselors, which trains men for this important service. In "The Atlantic Monthly" for November, 1909, Mr. William T. Miller, a teacher in the Wendell Phillips Grammar School, Boston, advocates the appointment in every high school of a Vocation Teacher, whose duty it should be to have interviews with each pupil on the subject of his ideas for the future, and help him in getting upon the right track and coming to some decision. He says:

"Many boys are entirely ignorant of all but three or four fields of endeavor; and if they could have presented to them the possibilities of certain uncrowded and congenial occupations their outlook would be much brighter. There are many ways in which a boy may choose unwisely in selecting a calling, and the presence of a trained vocational adviser should render such unwise choice much less frequent. Such an adviser can in most cases give more helpful direction than the parent, who is often misled by preconceived desires, or by false ideas of the relative dignity of different callings." After giv-

ing this interesting account of what a Vocation Teacher might do, Mr. Miller is compelled to say, "The Vocation Teacher, as such, does not exist."

This series of books on The Vocations is an attempt to meet this definite need. It is a pioneer in this new field of books expressly intended to interest and help young people during the adolescent period; just as "The Young Folks' Library," in its earlier volumes was the pioneer in offering a collection of twenty volumes of Fairy Tales, Folk Lore, Mythology, Biography, Adventure, Travel Stories, and Poetry. The present series is not only a complete and logical development within itself; but is a logical sequel to these preceding volumes. After play, work: after imagination, reality.

We should think ourselves badly treated if in buying our shoes we had to take the first pair offered; no matter how ill they might fit, or how badly they pinched; and then wear them until they wore out. Yet the worst pair of shoes will wear out in time.

A vocation on the contrary we choose "for better for worse, till death us do part." For learning one vocation takes so much time and strength, and training and standing in a new one are so hard to gain, that almost everybody has to abide by his first choice so long as he lives. Yet that choice is too often determined by accident, caprice or custom; and results in a lifelong misfit.

What an advantage it would be if boys and girls could try on these vocations, like shoes in a store, see how they fit, how they feel, how they look in the mirror, and then choose the one which will make them most useful and happy. The world of reality gives no such chance; but the world of literature does. To give boys and girls just this chance of a lifetime is the aim of these books on vocations.

We watch the craftsman, the engineer, the manufacturer transforming useless heaps of raw materials into useful articles and structures; and see whether the mechanic arts appeal to us.

We live in the open air with men and women who own the land under their feet, and the plants and animals around them; and see how we should like the life of the farm and the ranch.

We are welcomed to happy home circles; and see whether making such a home for ourselves should be part of our plan of life.

We enter the market place, where workers and work, supply and demand are brought together; where goods and services are delivered at the time and place where they are wanted most and therefore worth most; and find out whether business is the career for us.

We follow the fireman fighting fire; the life-saver rescuing a crew; soldiers and sailors defending their country; officials conducting town, city, state and national affairs; legislators making, and officers executing, laws; and see whether public service has a claim upon us.

We are introduced to men trained to fight the good fight of health against disease; justice against wrong; righteousness against sin; and find out whether we are called to the professions of medicine, law, and the ministry.

We go to school with men and women who enjoy some science or art so keenly that they devote their lives to handing on this knowledge, and the enjoyment of it, to successive classes, and see whether we should like to be teachers.

We become acquainted with men and women who express in letters the secrets of nature and the mysteries of the human heart; and discover whether there is a touch of this gift in us.

We share with musicians the long training and severe competition essential to success in their delicate and difficult art; and see whether we have sufficient talent and patience to follow so exacting a calling.

We enter the studio where toil, skill, and vision clothe lifeless matter with eternal beauty; and learn whether we could ever be artists.

These books are not manuals of technical instruction, but springs of personal inspiration, and tests of individual aptitude. Drawn from the description of experts, from biography and truthful fiction, they give the reader an appreciation of the pursuits of other men, and a revelation of his own capacities.

They make no apology for being compilations. A book on any of these vocations by a single writer would be dull and dry. It is only by bringing together from widely scattered sources vivid pictures of men doing splendid things — pictures struck off at white heat by writers thoroughly informed and passionately stirred by the kind of work which they describe, that one can make books on these subjects which will have enough variety and intense human interest, to induce young persons to read them.

While these books appeal directly to the interest and ambition of the reader, incidentally and unobtrusively, and therefore all the more effectively and acceptably, there runs through them a bright thread of idealism; presenting as the object of admiration in others and ambition for one's self not mere achievement, but achievement nobly won and generously used. If filling the mind with high ambition, and the heart with noble pleasure, in the pursuit of worthy ends is moral, then these books may be called moral. But they contain no preaching or lecturing on either virtue or vice.

To avoid possible misunderstanding, it is fair to state precisely what each contributor has done. At the outset I refused to have a merely nominal connection with the work; or to lend my name in a perfunctory way to plans devised and executed by other persons; having borrowed from President Cleveland the excellent rule never to have anything to do with any enterprise to which I could not make a substantial contribution, and for which I could not assume full responsibility. Accordingly the plan of the series as a whole, the general supervision of its execution, and the selection, as editors of the several volumes, of men who are, not merely men of general distinction, but leaders in the fields of activity which the books describe, has been my part.

The compilation of all the volumes is by Mr. Nathan Haskell Dole, Miss Caroline Ticknor and Mr. Albert W. Tolman. These editors have been employed for a year in making the selections.

All the material has been submitted to the editors of the several volumes; and in its final form has their expert approval. In almost every case the selections have been severely criticized, extensively supplemented, and greatly improved by the careful and conscientious work of these editors.

The work has not been easy; for we have been seeking for our selections almost mutually exclusive qualities — interest and stimulus to young people, and technical accuracy and reliability. To find interesting and stimulating accounts, avoiding the heavy and dull, has been the task of the editors of the series. To throw out the trivial and unworthy; and make sure that everything included is trustworthy and technically correct has been the work of the editors of the individual volumes.

The publishers have spared no necessary time, labor,

and expense to secure the best selections. In addition to acknowledgements made in the introductions to the several volumes, special thanks are due to the authors and publishers whose work is here reproduced with their kind and generous consent. To them is ultimately due the credit for whatever guidance and inspiration these books may bring to their youthful readers.

Wm. DeW. Hyde

Bowdoin College,
Brunswick, Maine,
Dec. 1, 1910.

INTRODUCTION

By

RICHARD COCKBURN MACLAURIN, Sc.D., LL.D.

This book is made up of a series of articles selected from those available for the purpose and put together with the object of presenting a picture of the life and work of the men employed in some branch of the great vocation of the Mechanic Arts. It is hoped that a study of the book will help young men who may be looking in this direction for their calling, to form a worthy conception of what that calling really means.

The question,— the momentous question, — What shall we do with our boys? is ever with us, always a source of anxious thought to the serious parent, and yet constantly being answered by him in the wrong way. Far too often he is unduly influenced by the consideration of what he would *like* his boy to do, or by his views as to the relative advantages of different professions for the acquisition of wealth, power, or social prestige. Perhaps the great question would be more wisely answered if it were put in the form, — What shall our boys do for themselves? It is they that are most directly affected by the answer, and the responsibility of deciding should generally be left to them, care being taken, of course, that they get the best guidance that is available.

The two essentials to real and complete success in any calling are *interest* and *capacity*. A man rarely does his best unless he is really interested, so that interest in one's work is naturally an important factor in success. Apart

altogether from this, however, is the fact that the pre-eminently happy man is the hard worker who really loves his work. All healthy young men look for happiness; too often, indeed, they demand it as a right. And it is not surprising that much of the disappointment, and, indeed, of the tragedy, of human life comes from the wrong choice of a profession. So much of the best of a man's life must be spent in work at his calling, that it is hard indeed for him to be other than unhappy if his work is uncongenial.

Interest, taste, inclination, however, are not enough. To these must be added capacity. How is a young man to determine whether he is capable of undertaking the work of a given profession? He must know what his powers are, and he must know what demands the profession will make upon those powers. The matter of self-knowledge is not easy, but it is of the first importance. The man who succeeds is he who knows what he can do and what he can *not* do, who forms purposes in accord with his knowledge, and having set his hand to the plow does not look back.

"How can a man come to know himself?" asks Goethe. "Never by thinking, but by *doing*." Hence, a young man must lose no opportunity of testing his powers by actual trial, and, if he be wise, he must choose that type of education that will give him a chance of trying those powers before the time for experiment passes by.

Let us suppose, however, that a young man has a reasonably accurate knowledge of his interests, his powers, and his limitations — even then it is no easy task to choose his calling wisely. He is handicapped by lack of experience of the world, and often has the vaguest ideas as to what a particular calling really means.

A study of the articles in this book should help him

by clearing his views as to the qualities and training that are really essential to success. It is impossible within reasonable limits to cover the whole field, for the term "Mechanic Arts," as used here, is wide enough to include everything that is done otherwise than by direct human toil. It comprehends the work not only of the humblest mechanic who is little more than a "hand" in a factory, but also of the man of large vision who opens up a continent by means of railroads, and of the genius who changes the whole atmosphere of human thought by the invention of the telegraph.

Many of its branches call for the highest powers of hand and head and heart. Indeed, if there is one thing that impresses itself on the reader of this book, it must be the need for the finest human qualities in much of the work that is described. Courage, endurance, pluck, honesty, accuracy, resourcefulness, alertness, tact, largeness of vision, insight, genius, — all have their place. These are qualities largely inborn in a man, but most of them are capable of training and of modification. The few men of exceptional powers often owe less to education than their less gifted brethren, for "God is not particular about the education of his favorite children."

To the great majority, however, education is a matter of vital importance, and, as time goes on, it must inevitably be of greater importance in the domain of the Mechanic Arts. More and more is this field coming under the sway of science, and to this there is no royal road — it can be reached only by patient and strenuous effort.

The sooner a young man realizes that he is living in an age dominated by science, the better for his chances of success and of social usefulness. There was a time when "common sense" and "mother wit" formed a

sufficient stock in trade for almost anything, but that time is quite gone by in the field of the Mechanic Arts. The progress here that has revolutionized the world is practically all due to science and its applications, and the man who is to be abreast of the movement of the day must have mastered the basic scientific principles. There is nothing mysterious in science, although seeming miracles have been performed in its name. It merely holds fast to the solid ground of fact, demands freedom from prejudice and from undue respect to authority, emphasizes the need of the open eye and open mind, and calls on all its adherents to observe, to observe, and once more to observe. To catch its spirit and to acquire its method is one of the hardest lessons that a man can learn in life; but a wise man will sacrifice much to secure it. It does not come by nature, it must be acquired by careful training. The schools can do much to foster it, although they too often do their work so badly as to destroy it altogether. Great is the risk that a young man takes in going to an indifferent school, and the very best school available is the only one that should be thought of by those responsible for his education.

Although the scientific method and spirit are of the first importance in much of the work that comes within the range of our consideration here, something more than method and spirit is required. This something more is *knowledge.* In many branches of the profession an enormous amount of knowledge is required, and this knowledge must be as accurate as it is extensive. In many cases it will take years of hard work after the high school has been left behind before even the essentials of this knowledge can be properly mastered, and the ablest and most successful men will go on adding to their knowledge almost daily until all work ceases.

To supply the necessary preliminary training, to impart the essential facts and principles, and to give men an insight into the scientific method and spirit, is the work of the technical schools. These schools are fortunately numerous to-day, being scattered throughout the length and breadth of the Union — either as separate institutions or as professional schools in our universities. The establishment of the older of these almost half a century ago was part of a world-wide movement making for the recognition of the claims of science and of its importance in the realms of thought and action. For centuries the world of education had been dominated by what is known as the classical tradition, most of what was best in that tradition having been derived from the classic thinkers of antiquity. Needless to say, there was much, very much, that was good in that education, much that we could ill afford to lose sight of now or at any time in the future. Its chief defect was that it failed to recognize that the world has moved considerably since the days of Plato and of Aristotle, and that the greatest force in the modern world making for change is what goes by the name of science. Within the last few generations this force has been peculiarly effective, and has so completely changed the conditions of our daily lives that our grandfathers, looking down upon us, would feel that they observed a new heaven and a new earth.

The change has been most startling in the field of the Mechanic Arts, a field that under the new conditions offers splendid opportunity for individual advancement and for public service. And, surely, it is a most attractive field, presenting a wonderful variety of interests. The modern engineer is a true poet, a maker whose creations touch the imagination and move the world.

I 'm sick of all their quirks an' turns — the loves an' doves they dream —
Lord, send a man like Robbie Burns to sing the Song o' Steam!
To match wi' Scotia's noblest speech yon orchestra sublime
Whaurto — uplifted like the Just — the tail-rods mark the time,
The crank-throws give the double-bass, the feed-pump sobs an' heaves,
An' now the main eccentrics start their quarrel on the sheaves:
Her time, her own appointed time, the rocking link-head bides,
Till — hear that note? — the rod's return whings glimmerin' through the
guides.
They 're all awa! True beat, full power, the clangin' chorus goes
Clear to the tunnel where they sit, my purrin' dynamos.
Interdependence absolute, foreseen, ordained, decreed,
To work, ye 'll note, at any tilt an' every rate o' speed.
Fra' skylight-lift to furnace-bars, backed, bolted, braced an' stayed;
An' singin' like the Mornin' Stars for joy that they are made;
While, out o' touch o' vanity, the sweatin' thrust-block says:
"Not unto us the praise, or man — not unto us the praise!"

In this hymn of McAndrew it is the glory of steam that is extolled, but Kipling might equally well have been inspired by electricity or by chemistry or by almost any other power in the realm of the Mechanic Arts. We are so used to the magic influences of electricity that we rarely pause to appreciate its marvels. Go to Niagara, or some other of our great waterfalls, and try to realize the fact that the water as it falls is (thanks to electric agencies) lighting cities more than a hundred miles away, driving their street cars, grinding their wheat, making their shoes, printing their newspapers, and cooking their food. Not only has electricity thus wonderfully lightened the load of human labor, but, as we all know, in its quiet way it has bridged the Atlantic and almost abolished distance by enabling us to communicate easily and rapidly with our fellows hundreds of miles away.

There are some shortsighted people who see in these developments, due to the Mechanic Arts, a mere change in material things, but no one who looks below the surface can fail to recognize that such material changes pro-

foundly affect the mental and the moral outlook of our race. And certainly no young man of high purpose should hold back from entering into the training that leads to these professions from the fear, often suggested by foolish people, that the studies that he will have to pursue are mere "bread and butter" studies. In so far as these studies enable him to be a useful member of society they will have a "bread and butter" value, and bread and butter are rarely despised in practice by sensible men, however loftily they may affect to disparage them. If these studies are pursued as they should be they will have no narrowing influence, but, on the contrary, will greatly widen the student's outlook and sympathies. They will show him, too, a splendid way to be of real use in the world, which cries aloud now and always for men who are really efficient, for men who have not only the will, but the power to serve society honorably and well.

Richard C Maclaurin

Mass. Institute of Technology
Boston, Mass.
June 22, 1910

THE MECHANIC ARTS

THE RAILROAD CONQUEST OF THE MOUNTAINS[1]

BY C. M. KEYS

WHEN a writer seeks picturesqueness in a railroad story he turns naturally to the engineers. When he has gone the rounds, interviewed every chief-engineer and every railroad president in town, he comes at last to Number 1, Broadway, and finds General Grenville M. Dodge. He cannot miss that trail, for every engineer and every president will begin his conversation with the remark:

"General Dodge is the man you ought to see!"

He sits at a big oak desk in a high office on the south side of the building beside a window that affords him a sweeping view of the two rivers and the harbor, away down beyond the Narrows.

He is an old man now — seventy-six by the calendar — but he neither looks it nor acts it. He is still chairman of the board for a company or two, and his associates vouch for it that he is no "dummy director." His face is weather-beaten and gray, but his eyes are still the eyes of the major-general who won his stars with Sherman and with Grant, and who led the forces of the Union in more than one of the Indian campaigns.

[1] From "The World's Work." By permission of Doubleday, Page & Company. Copyright, 1907.

The purpose of this article is to give to the uninitiated some faint idea of the methods that are followed in the building of the great railroads through the mountain regions. General Dodge's expeditions in search of a route for the Union Pacific illustrate very aptly the methods and purposes of what is technically called a "reconnaissance." For that reason it will be referred to quite frequently in this article.

Roughly, a new railroad may be said to begin with this reconnaissance. It is simply a trip over the ground made by a man or men with, as they say, "an eye for the country." This means that the head of the party must be qualified by nature and experience to take in all the essential details of the country, its physical capability to support a railroad, its natural obstacles, the nature of its rock formations, its soil, and all other broad characteristics. His report is not greatly detailed. He will, perhaps, recommend that the surveys take the south side of a certain ridge because of the freedom from snow-slides; or the north side of another ridge, because the south side is rock while the north side is loam. He may narrow the choice of mountain passes to two or three. Occasionally, he will select the pass, as General Dodge selected the Sherman Pass by which the railroad crosses the Black Hills.

When the reports of all the reconnaissances are digested the preliminary survey begins. This is usually in detail, but it is not quite final. In the case of the new Tidewater Railroad, in Virginia, these surveys left a choice on some divisions between as many as twelve routes to be decided by the chief engineers and the directors. Each alternative route, however, is fully detailed. For instance, if the survey shows a cut through a hill, it is supposed to show also whether the cut is through rock, sand, clay, shale, loam,

or any other substance. Grades are carefully figured, as also curvature, bridges, fills, and cuts.

The next step is the location of the line. This is decided from the surveys. The report of the location must be in the fullest detail, every hollow, every rock, every river being minutely examined and measured. The letting of the contracts for construction is based upon this location. If an engineer errs by so much as reporting a ledge of shale in the side of a hill instead of a ledge of granite, this mistake throws out the estimate of "first cost" by just so much. On a single mile of road, that one mistake may make a difference of nearly ten thousand dollars in the cost of construction.

So much for the routine by which the placing of a new line is accomplished. It is very simple, of course. If there is one thing that stands out from it quite clearly, it is that the effectiveness of this routine and the perfection of the work accomplished through it depend directly upon the men who put it into execution. That points to the civil engineer.

The cream of this profession rises thin. It is a strange and interesting fact that nearly all the great railroads through the Rocky Mountains were surveyed and carried through by the same men. Of course, each system had some new men, but the backbone of the staff in each instance seems to have been composed of the engineers who ran the Union Pacific and the Central Pacific to a junction at Promontory, Utah, in 1869. They met again at Sierra Blanca, when Mr. Gould's Texas Pacific joined Mr. Huntington's Southern Pacific, and yet again on the Santa Fe, the Northern Pacific and the Canadian Pacific when the rails from the West met the rails from the East. To-day most of these veterans are gone, but here and there one may be found holding an honorable post. For instance,

Mr. Robert Blickensderfer, consulting engineer of the Wheeling & Lake Erie at Pittsburg, helped to build the Santa Fe, the Missouri Pacific, the St. Louis & San Francisco, and the Union Pacific. General Dodge was a factor in building the Union Pacific, the Texas Pacific, the Fort Worth & Denver City, and the Missouri, Kansas & Texas Railroads.

Let us start with the first reconnaissance of the first transcontinental line, the Union Pacific. It was headed by Peter A. Dey, with Grenville M. Dodge as first assistant. They crossed the Missouri River at the point where Omaha now stands, and General Dodge will not commit himself as to whether they used a raft or a flat-boat. In any case, it was no palatial ferry. They struck out into a howling wild. One incident will serve very well to illustrate the nature of the expedition and the country. It is told by the General himself in a speech that he made in 1888, a copy of which he gave to the writer for use in this connection:

"When I crossed my party over to make the first explorations, not one of us had any knowledge of the Indians, of the language, or of plainscraft. The Indians surrounded our wagons, took what they wanted, and dubbed us 'squaws.' In my exploring, ahead and alone, I struck the Elkhorn River about noon. Being tired, I hid my rifle, saddle, and blanket, sauntered out into a secluded place in the woods with my pony, and lay down to sleep. I was awakened and found my pony gone. I looked out into the valley and saw an Indian running off with him. I was twenty-five miles from my party, and was terrified. It was my first experience, for I was very young. What possessed me I do not know, but I grabbed my rifle and started after the Indian, hollooing at the top of my voice. The pony held back, and the Indian, seeing me gaining

upon him, let the horse go and put the Elkhorn between us. The Indian was a Pawnee. He served under me in 1865, and said to me that I made so much noise he was 'heap scared.'"

For eight years they carried on that survey, learning as they went much about these Indians. They followed the trail of the fur-seekers, broken wide by the Mormons in their long pilgrimage. When the settlers' movement to California began, General Dodge made a map to guide the feet of the emigrants. It took the trail from Omaha up the Platte Valley, across the hills through Salt Lake City, thence by the Humbolt and Truckee Valleys to California. It showed the camping places for each night, indicated where grass, water, and wood could be found, and marked the fords of the rivers. It was not intended as a report of a railroad reconnaissance, but it will serve to show the variety of information gathered up by a skilled railroad scout on a pilgrimage through a country.

On a much later expedition General Dodge discovered the Sherman Pass. He was coming back from the Powder River campaign against the Indians. With six troopers and a guide, he left his force and rode miles along the ridge of the hills. His little party was cut off the main force by a body of hostiles. All the afternoon they rode for their lives, holding off the Indians by rifle fire. They came, at last, down into the level plains.

"I then said to my guide that if we saved our scalps, I believed we had found the crossing of the Black Hills — and it was over this very ridge that the wonderful line was built. For over two years all explorations had failed to find a satisfactory crossing."

"In 1867 . . . we located there the post of D. A. Russell and the city of Cheyenne. At that time, the nearest settlement was at Denver, 150 miles away; and while we

lay there the Indians swooped down on a Mormon train that had followed our trail, and killed two of its men; but we saved their stock, and started the graveyard of the future city."

These are but episodes of the reconnaissance of the Union Pacific. They can be duplicated from the history of every one of the transcontinentals.

The original survey of the Canadian Pacific route through the Rocky Mountains was as difficult a piece of work as could be imagined. The two ranges are very close together, and it seemed simply impossible for any road to find its way across them, on account of the great depth of the narrow valley between them. To-day, the trains pass through the eastern range in the Kicking Horse Pass and the western range in the Eagle Pass. The former, according to Gereral Sherman's statement, was discovered by an American engineer named Randolph, and was named from the fact that his horse kicked him on the knee at that stage in his wanderings. The passage of this range had been practically given up, and a great détour through Howes Pass was intended.

Eagle Pass was discovered by accident. General Sherman credits the same Randolph with its discovery, but the records are against him. Years before, when the Canadian engineers were seeking a route for a wagon road from British Columbia, Walter Moberly, head of a surveying party running the line from west to east, was led by an eagle's flight through this almost impenetrable range of the Selkirks. He was on the point of turning back, weary and discouraged from a long search for a passage, when an eagle swept over his head and on into the heart of the range. He followed it around a great projecting corner, up a huge rift in the side of the glacier — and then the pass opened clear before his eyes. It is that same rift

that to-day carries the rails of the Canadian Pacific from the snows to the valleys of the coast.

Many a mile of these great railroads was laid beside the graves of the engineers. Down in the heart of Mexico, in the rolling hills of sand, there is a little group of graves, marked by white crosses. They are merely a typical tribute to the perils of reconnaissance in a savage country. Four young American engineers building the Mexican Central were caught at that point in 1881 by the Apaches. They fought until they died, fearing the torture. Their names were Fordham, Leavitt, Grew, and Wallace; and that is about all that the records show. It was but an incident, — no more, — echoed in Texas when they shoved the Texas Pacific through the Staked Plain; paralleled in Idaho on the Northern Pacific survey.

The reconnaissance, however, is but a little part of the location of a railroad through the wilds. The survey follows it. In most cases, the final route of a railroad across the ranges threads the valley of a river. It is so that the Denver & Rio Grande pierces the Rockies, following the cañons of the Grand and the Gunnison. Here the engineer meets other dangers than the hostility of man. Along these frowning cliffs, towering to the snows, the line must find a foothold. Great logs are slung in chains above stream for men to stand upon while they plot out the level of the ledge. Sometimes men are dropped over the cliffs to operate their transits and their levels from the end of a rope, dangling above a torrent.

The life in the field is rigorous. From the dawn come the feet of the engineers, up through the passes of the mountains. Here go the ax-men to clear a path for the guiding flag of the "front flag-man." Behind them trails the transit-man to measure the distances and the angles; and with him comes his staff of ax-men and flag-men.

Behind him, again, follows the leveler, to record the levels, and with him are ax-men and rod-men. Sometimes there follows a topographer, somewhat of an artist, who makes a clay model of the general contour, not merely of the line but of the country round about as well. So they travel on their way, merely making notes as they go, and leaving here a stake, and there another stake.

When the light fails, they travel back to camp. In flat country, where the work is swift, the camp moves on as the men progress, making fast stages. In plotting a route through the mountains, the camp is usually located at one point for weeks. In such a case, light shacks spring up; but usually the work is done under canvas. A tent serves for kitchen, dining-room and commissionary. Another shelters the rod-men, ax-men, transit-men, and levelers. Yet another covers the heads of the survey. In this last, work goes on by night as well as by day. The notes of the day's work are gone over, plotted, made into a rough sketch of the line surveyed.

It is no easy life, but it has many compensations. In exceptional cases, two or three years in the ranks lead to a promotion to be an assistant engineer on some great project. This happened in the case of General Dodge, and in the case of the late Alexander J. Cassatt. As a rule, however, progress is made through the regular routine from ax-man to rod-man, then transit-man, then leveler, then assistant engineer.

From this routine have graduated many of the men whose names stand high in the list of railroad officials of America. Hence came the president of the Pennsylvania, James McCrea, and the third vice-president, Samuel Rea. Howard Elliott, H. B. Ledyard, W. J. Wilgus, and dozens of others of high rank began their work carrying an axe or a chain in a surveying party.

To-day it would perhaps be invidious to try to declare that any one man overtops his fellows among the locating engineers. In the profession, John M. Graham of the Erie, E. H. McHenry of the New Haven, William Hood of the Southern Pacific, and J. B. Berry of the Rock Island enjoy great reputations, based upon the work that they have done and the positions that they have won.

The "locating engineer" does not do all the work by any means. He but outlines the work that is to be done. When the "location" is completed, there follows the task of building according to that location. In this work the construction engineer takes command. He belongs to a class that covers all branches, civil and mechanical engineering, bridge building, and that rare faculty that finds its expression in the executive handling of great armies of men. In this field the greatest danger to life is encountered, and here the finest genius of the American railroad builder has found its expression. The keynote of the successful construction engineer is resourcefulness. He must be stopped by nothing in the world.

"Can you build a one per cent line through the Sierras?" I asked, dubiously, of one of the consulting engineers of the Western Pacific.

"Sure we can — and we will," he said, "for if you give an engineer enough money he can build any kind of a line anywhere."

To-day, the profile of that road shows a maximum grade of only one per cent, fifty-two feet to the mile, through the snow-capped mountains that, of all others, seemed most forbidding.

The grade has not been easy to obtain. To get it the builders have upset most of the traditions of the Sierra Nevada. They have passed "impassable" hills, and sounded "bottomless" chasms; they have made a path

through "pathless" forests, and tunneled through "impenetrable" mountain ranges. They have called upon the flower of the engineering profession, it is true, and have spent the money of the Goulds as a spendthrift throws his wealth to the winds. But they have done the thing that many men of many decades have declared was a thing impossible. They have run a low-grade line through the crests of the Sierras.

The engineer who has charge of the construction of such a line has a difficult task indeed. If he is given the two termini and told merely to get a line between them with so much grade, the task is relatively easy. He will run his road around in circles, picking his way along a river bed, making spirals about some towering peak, following the meanderings of some volcanic rift. So most of the old mountain roads were laid down.

The trunk line needs more than that. Not only does it want light grades, but it must be direct, and it should be relatively free from curves. Instead of following a stream, it cuts across the loops. In a case like the Tidewater Railroad, this task is titanic. The rivers run in deep cuts. Cutting across them means little more than making a series of tunnels and bridges, each bridge leaping from the mouth of one tunnel to the mouth of another.

It is very simple, but enormously expensive. It is followed, in some measure, by the Tidewater, the Moffat Line, and the Western Pacific. It is given to only a few engineers to build a road like that. Most of them have had hard struggles to get their plans passed by the board of directors. They have had to show that the line was both best and cheapest. Mr. Berry was given the job of straightening the Union Pacific, but that was reconstruction — merely a move in the imperial game played

by Mr. Harriman, who has had respect neither for lakes, nor mountains, nor money.

When a railroad follows a river, which after all is the most common form of the mountain pass, the work may be very simple, or very severe. In broad alluvial bottoms, the grading is as easy and fast as on a prairie, the main problem being to raise the grade above high water. When the river is a mountain torrent flowing through a cañon, like the Gunnison, the Grand, or the Fraser, the work of the engineer is monumental.

In Frémont County, Colorado, for instance, the Denver & Rio Grande winds for miles along ledges cut in the towering cliffs. At one point it was impossible to cut the ledge, so they leaned great steel girders against the rocks, and swung a bridge to carry the line. In the Gunnison, with the river roaring below, they hung their working forces over the cliffs in ropes to cut out a foothold from which to begin the drilling, blasting, and shoveling. In the Fraser Cañon, the Canadian Pacific did all that was known to the engineering profession, then invented new methods. Here they cut great ledges in the slopes; there they built new ledges, sticking them to the mountain sides as a swallow builds her nest; there, again, they sluiced great rifts in the hills to fill their trestles with gravel.

Sometimes these mountain roads turn round upon themselves, making great loops merely to gain a few feet of climb. To make two miles, the Canadian Pacific train in one place travels nearly seven miles, and turns enough corners to make twelve complete circles. At Georgetown, Colorado, the Union Pacific gains a few yards of height by a great loop; and this is a method that is not at all uncommon. The Gothard Tunnel, in Europe, makes two complete circles in the very heart of the mountain itself. It is on the principle of a spiral, and is only used to over-

come a rise too sharp to be surmounted by any direct line that could be surveyed.

One of the greatest difficulties that confront the construction engineer is the rift in the mountain side. If the road is following a ledge along the cliff and comes suddenly upon a great deep chasm running far into the hill, heroic methods are needed. Across such a rift the Canadian Pacific threw a wooden trestle. It went down with the first train of gravel. Van Horne, an American who has done things, fixed that rift. He built across it a great stone bridge, anchored into the cliff, which stands to-day as a monument to prove that nothing can stop the construction engineer.

In the Sierras and the Selkirks, in particular, the avalanche is a terrible enemy. Of course, the first survey notes the courses usually followed by these great slides. Seasons are then spent in studying them and all available records are consulted. Competent engineers are detailed to make a report on just what must be done to meet them. As a rule, the surveys make it clear how much can be left unprotected, and how much must be snow-shedded.

Where the track climbs along a cliff transversely to the path of the slides, a sort of artificial tunnel is built along the upper side of the regular track. The ledge is widened to permit of a structure being built to occupy a width of from twenty to thirty-five feet. It is about twenty-two feet high. The part of it that lies alongside the summer track is a hollow tube, built of strong timbers, completely covered over. Behind this is built a crib of timbers, and the whole gap behind the tunnel is filled with rock, earth, and sometimes masonry, to bring the slope of the mountain over the top of the shed. The snow-slide goes harmlessly over the tops of the trains running within this shed.

The men who plan all these things and the men who do

them lead lives far different from the life of the ordinary man. Unluckily, it has come to be recognized almost as a convention that the railroad camp pushing the lines in the West need have no morals. The prairie sections of the Canadian Pacific were built without the usual accompaniment of rum, immorality, and crime, but the bars were let down in the mountain sections. On our own roads it was uniformly bad.

It took two years and a half to build the Canadian Pacific through the Fraser River Cañon. In that construction thirty-two men lost their lives through accident. No one has ever dared to compute the number of men that paid with their lives for the riot and vice of the railroad camps, but it is conceded that the work of the building was not half so disastrous as the "pleasure" of the idle days and nights. A blow came to follow a word, and the flash of a knife or the crack of a pistol came to follow the blow. Graves, unnumbered and nameless, mark the path of the pioneer railroads through the great mountains.

It is little better to-day than it was in the early days. The camps that now lie in the heart of "Bret Harte's land," running the line of the Western Pacific, are just as were the "roaring" camps of the last generation, save that they lack Bret Harte. The engineers still lose themselves in the deep snow, perish by falls from the cliffs, are swept away by the strong rivers.

The "company boarding houses" along the Sierra still serve their patrons with bacon, beans, and hard black bread, the only noticeable difference being that nowadays the weekly charge for the same is five dollars instead of a dollar and a half. The den, the dance-hall, the saloon still cast their lurid lights across the midnight camp in the rift of the snow-capped Rockies, where the army of "Jim" Hill is fighting the cliffs of the Columbia to build that

anomalous "water-grade" through the very heart of the great mountains.

But, with all their crudity and cruelty, the forces gain their end. There is no mountain range on the whole American Continent that can to-day strike terror to the heart of the man with the transit and the level.

Though ropes will break, men will take long chances so long as the world endures. A one-inch rope once frayed out along the verge of the Gunnison Cañon and the Denver & Rio Grande lost one of its best young engineers. A little carelessness, a misstep, a tumble, a cry from the black ravine — and the songs in the camp are hushed that night. But the spirits of the pioneers are elastic, and the work brings swift forgetfulness.

THE SEA-BUILDERS[1]

By RAY STANNARD BAKER

UPON a dark night, the entire Atlantic coast of the United States from the easternmost point of Maine to Cape Lookout in North Carolina is marked with lights like a city street. Before the watch on a coastwise steamer plying down loses one light over the vessel's stern, another flashes white or red above the prow. Southward from Cape Lookout to the tip of Florida, around the Gulf of Mexico, and up the Pacific coast, a steamer is never more than two hours' sailing beyond the range of some one of these signboards of the sea. Every harbor fairway on the entire twenty-five thousand miles of coast-line bears its own distinctive lights and buoys, so that even the most blunder-headed skipper can not go astray. The navigator of fresh water may travel the length of the great lakes and up the Mississippi, or up any one of a score of other great rivers, and find a warning light blinking at him from every bar and reef.

In its solicitude for the ships that seek its harbors, the United States Government maintains more than eleven hundred lighthouses and lighted beacons; eighty-eight light-vessels and lantern buoys; and nearly eighteen hundred post lights, most of which mark the shores of navigable rivers. Three hundred and fifty-four siren signals, besides other hundreds operated in connection with the regular lighthouse service, blow a deep bass warning at

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the rising of a fog. Whistling-buoys, bell-buoys, and shoal-buoys to the number of nearly five thousand are distributed along the channels of a hundred harbors. In the daytime dangerous bits of coast or river are indicated by four hundred and thirty-four day beacons. A fleet of forty-one vessels and more than forty-two hundred men are required to attend, repair, and supply these aids to navigation; the cost to the people of the country being between three and four million a year.

A large proportion of the lighthouses, which are by far the most important governmental works for the protection of the mariner, are built on land well above the wash of the sea, where the construction requires only the ordinary skill of the carpenter, the mason, and the iron-worker. The small remaining residue, the off-shore lights, built in the most difficult and dangerous locations that can be selected, have cost more, both in construction and in subsequent maintenance, than all the others put together.

The true sea-builder speaks with something akin to contempt for the ordinary shore light. He must have tides, breakers, ice-packs, wrecks, fierce currents, and wind storms to test his mettle and to show what he can do. Not only must he be a skilled engineer and builder, but he has need of the mysterious human elements of courage, executive foresight, resourcefulness in the face of danger and perseverance in surmounting obstacles.

In lighthouse building, the stone-tower light easily takes precedence both in age and in the difficulties and dangers which attend its construction. A little more than one hundred and forty years ago, John Smeaton, a maker of odd and intricate scientific instruments and a dabbler in mechanical engineering, was called upon to place a light on the bold reefs of Eddystone, near Plymouth, England, and to him the world owes the idea of building a light-

house in the form of a solid stone tower. In stone-tower lights, as in all other kinds, the first and greatest difficulty which the builder has to meet lies in placing the foundation.

For instance, when Captain Alexander began work on Minot's Ledge, in 1855, he had an apparently impossible problem to solve. A bold, black knob of rock lay in the sea just off the southeastern chop of Massachusetts Bay. At high tide the waters covered it entirely, and its place was indicated by a few restless breakers, or, if the water was very calm, by a smooth, oily, treacherous eddy. At the lowest tide, a glistening head, laced around with a collar of surf, protruded a few feet above the surface of the water. In thirty years' time forty-three vessels had been dashed to pieces upon it, twenty-seven of which were totally lost, together with their crews. A small light, propped on wrought-iron piles, had already occupied the rock; but on a stormy night in April, 1851, while the bell in the tower was ringing furiously, the waves and the wind twisted it from its moorings, and hurled it more than a hundred feet off into the sea, carrying the keepers with it. Upon this ill-fated rock Captain Alexander agreed to build a stone tower one hundred and six feet high and thirty feet in diameter at the base. On his first visit to the reef, it was so slippery with sea moss, and the waves dashed over it so fiercely, that he could not maintain his footing. Part of the ledge was always covered with water, and the remainder, even at low tide, was never bare more than three or four hours at a time.

Captain Alexander sent a crew of men to the rock to scrape it clear of weeds and to cut level steps on which they could maintain a firm footing. They worked with desperate haste and energy. When a great wave came rolling in from the sea, the foreman shouted, and they all fell on their faces, clinging together, and held their breath

until the rock was bare again. Sometimes when a storm blew up suddenly and the boats dared not approach near enough to effect a landing, the boatswain was accustomed to cast out a line. One of the workmen would seize it, make it fast to his wrist, and plunge boldly into the sea. Then the sailors would pull him in like a great clumsy cod.

Working in instant danger of their lives, and continually drenched and suffering from the smarting of salt-water sores, Captain Alexander's men were able to cut only four or five little foot-holes in the rock during the whole of the first season. But they could console themselves with the fact that it took Winstanley, in building the first Eddystone light, four years to drill twelve foundation holes and fit them with iron rods.

In the second year, the workmen succeeded in building an iron platform twenty feet above low water. Ropes were stretched between the piles on which it rested, and when the waves were high, the men clung to them to prevent being washed into the sea. The next winter a big coastwise bark, driven in by a storm, swept away the platform, crushed the face of the rock, and ruined the result of two years of hard work in a single night.

In the third year, the workmen succeeded in laying four foundation stones; and in the fifth year, the six lower courses of the tower were completed. The work of fitting the stones in place was full of excitement. Stout bags of sand were swung on a crane from a boat to the rock. While they were pitching and tossing in the air, the men caught them, and piled them up in the form of a small pen, and rammed them firmly together. Sometimes it took three or four staggering men, each clinging with one hand to the life-ropes, to handle a single bag. The inside of this primitive cofferdam was then bailed out, and wiped dry with a sponge.

Meantime, the men on the boat had prepared the stone by laying it on a piece of thin muslin covered with mortar, like a mustard plaster. The edges of the muslin were then drawn up around the top of the stone, and it was lowered into the coffer-dam. Each stone was dovetailed so that it fitted closely into the stone next adjoining it in the course. The difficulty of fitting a stone held aloft on a swinging crane with the waves dashing around the workmen's legs can well be imagined. Quantities of sledges and drills were swept from the rock and lost. One of the more inventive workmen conceived the idea of wearing a life-belt and fastening his sledge to his wrist. This method was generally adopted, and it worked admirably until a breaker washed one of the men off the rock. Owing to the weight on his wrist, he went down head first, and his legs were left sprawling above the surface of the water. He was rescued with the greatest difficulty.

In five years' time the light was finished, "rising sheer out of the sea," as Longfellow describes it, "like a huge stone cannon, mouth upward." It cost the government three hundred thousand dollars.

The devotion and the loyalty of the lighthouse builder approach the enthusiasm of the soldier in the heat of battle. When the first of that famous family of engineers, the Stevensons, was building the Bell Rock Light on the Inchcape Reef, his Scotchmen worked with the desperation of despair. Only two could remain on the rock at a time, but they stuck there with the tenacity of leeches, the cold water of the North Sea bearing down every few minutes and whipping entirely over them.

In describing the progress of the work, Stevenson tells with quaint humor how the drenched workers were cheered by a sailor on board the work-ship who played sweetly on

a German flute. Iron rods were fastened into the reef to hold the courses of the tower. When the first stone was at last swung out on the tipsy crane, the workmen, ragged and chilled, and worn with the hard struggle, clung to the iron rods and cheered madly, like soldiers just over the crest of an enemy's fort.

One of the most difficult of all stone-tower lighthouses to build was the Spectacle Reef Light, in the northern end of Lake Huron, near the Straits of Mackinac. Here the problem was to deal not with tides or heavy seas, but with the crushing force of the ice-packs that came down out of the North and moved with all of the mighty power of a glacier. The site of the tower was a lone rock lying more than ten miles from land and eleven feet under the surface of the water.

At first the engineers declared the work impossible of accomplishment, but the wreck of a number of valuable vessels on the reef spurred them to attempt it. The plans were drawn by General O. M. Poe, who was Sherman's chief engineer on the famous march to the sea. An enormous wooden crib, ninety-two feet square, twenty-four feet high, and enclosing a space sixty-eight feet square, was built at a harbor twelve miles away, and towed out to the rock. Here it was sunk to the bottom, and weighted with stone, and thus was formed a quiet pond in which the work could be prosecuted. A bottomless tub, thirty-six feet in diameter and having staves fourteen feet long, was now built, and suspended exactly over the site of the tower. A rope of oakum was tacked to its lower edge; and then when a diver had cleaned off the rock below, the tub was lowered into the water and down to the rock. The staves were mauled down until each pressed close down on the rock. Then the divers, toiling in the icy water, filled all of the openings around the bottom of the

tub with hay and Portland cement. The tub being thus made perfectly tight, a huge pump soon emptied it of all the water, and the rock lay clean and bare, ready for the workmen.

Owing to the approach of winter, great haste was necessary to secure the preliminary work so that it would not be affected by the ice. Not infrequently the men were called out at three o'clock in the morning, and they were allowed only a few minutes for meals during a day's work, which often lasted from eighteen to twenty-one hours. During the last days of the season, snow and sleet fell almost constantly, and the waves frequently dashed over the breakwater, keeping the men drenched.

The next summer the work was continued with renewed zeal. For the first thirty-four feet, the tower was built of solid masonry, thirty-two feet in diameter, the stones all dovetailed firmly together, and the courses attached one to another with heavy iron rods. In the top of the tower, five keepers' rooms were built, one above the other, and connected with spiral stairways. Far up at the pinnacle stands the cylindrical box of iron and glass which protects the light. The cost of the Spectacle Reef tower was three hundred and seventy-five thousand dollars. In the spring after it was finished, the work of the builders was given a remarkable test. The keepers, returning to their sturdy charge, found the hitherto irresistible ice-pack piled to a depth of more than thirty feet around the tower, so that they had to cut their way in to the door. Following General Poe's plans, a similar lighthouse was afterwards constructed on Stannard Rock, in Lake Superior.

Even more formidable difficulties and dangers were encountered in building Tillamook lighthouse, off the coast of Oregon. While its foundation is not submerged, yet because of its exposed position in the ocean it belongs

properly among the off-shore lights. The island rock on which it rests rises a sheer eighty feet above a brawling sea. It is only a mile from the mainland, but the nearest harbor, owing to the precipitous shores, is twenty miles away, at the mouth of the Columbia River. So violent are the waves that break around the ragged edges of the island, that only with the utmost difficulty the surveyors made their first landings.

One expedition was headed by an experienced English lighthouse builder named Trewavas. When he reached the rock, it was edged with surf, although the sea outside was almost wholly calm. When the boat was swept up close to the rock, he and one of the sailors leaped for shore. Trewavas stumbled, and was carried out to sea, and drowned in sight of his boat's crew.

One of the earliest and oddest difficulties with which the Tillamook builders had to contend was an immense herd of sea-lions, which defended their ancient citadel with persistent valor. Before the workmen were allowed undisputed possession, they were compelled to arm themselves, and drive the herd repeatedly into the sea.

Owing to the great difficulty in making landings, most of the workmen were sent to the rock in a breeches-buoy. A thick hawser was stretched from the summit of the island to the mast of a ship lying three hundred feet away in calm water. Along this traveled the buoy, which consisted of a life-preserver fastened to a stout pair of breeches cut off at the knees. Sometimes when the water was a trifle rough, giving the ship a rolling motion, the hawser would slacken suddenly, let the buoy and its passenger drop with sickening velocity into the sea, and then snatch them out, and hurl them fiercely a hundred feet in air. Only men of seasoned pluck could be persuaded to make this trip at all.

A large crew were finally landed, with supplies enough to last them several months, and at the coming of winter and rough weather the ship was compelled to leave them to their fate. One night in January, a tornado drove the waves entirely over the rock, crushing the tent in which the men slept, and washing away most of their provisions and nearly all of their tools, clothing, and equipment. For days at a time, in the coldest weather of a northern winter, they were compelled to lie clinging to the slippery rock, drenched with icy water, exposed to swiftly succeeding storms of snow and sleet, and cut by the sharp sea winds.

During all of this time they had no sufficient means of warming themselves, practically no fresh water to drink, and nothing to eat but hard-tack and bacon, soaked in sea water. Few Arctic explorers have had to suffer the perils and privations to which these lighthouse builders were subjected. And yet they lived, and built a great lighthouse on the summit of the rock.

Colonel G. L. Gillespie, the engineer who had charge of this wonderful work, tells an amusing story of the difficulties of the lighthouse establishment in finding a cook who was willing to live on the rock, cut off wholly for months at a time from communication with the outside world. Finally, a portly, good-natured German named Greuber agreed to accept the position. He was promptly sent down to Tillamook, but when he saw the tossing breeches-buoy in which he was expected to make the passage to the rock, he held fast to the rail of the ship. "I'm too fat," he explained.

On his return to Astoria his friends made so much fun of him that he declared he would go to the rock if it killed him. He turned as white as chalk when the buoy was strapped around him, but he made the trip without even

wetting his feet. After that, however, nothing would persuade him to venture again in the perilous buoy, and he died recently on the rock after nearly sixteen years of continuous service there.

The builder of Race Rock Light, in Long Island Sound, was Mr. F. Hopkinson Smith, known as the author of "Colonel Carter" and "Caleb West." Here again the work of construction was fraught with extraordinary difficulties and dangers. The foundation rock is just off Fisher's Island Sound, at a point where the water rushes both ways, according to the tide, with great force. A quantity of stone riprap was thrown into the swift water, where it was arranged by divers, and then covered with a circular mass of concrete on which a tower of solid granite was constructed.

A stone-tower lighthouse bears much the same relation to an iron-pile lighthouse that a sturdy oak bears to a willow twig. One meets the fury of wind and wave by stern resistance, opposing force to force; the other conquers its difficulties by avoiding them. The principles of construction in the two are entirely different, and the builder of the screw-pile or disk-pile light is confronted by his own peculiar problems and dangers.

For southern waters, where there is no danger of moving ice-packs, iron-pile lighthouses have been found very useful, although the action of the salt water on the iron piling necessitates frequent repairs. More than eighty lights of this description dot the shoals of Florida and the adjoining States. Some of the oldest ones still remain in use in the North, notably the one on Brandywine Shoal, in Delaware Bay, but it has been found necessary to surround them with strongly built ice-breakers.

Two magnificent iron-pile lights are found on Fowey Rocks and American Shoal, off the coast of Florida, the

first of which was built with much difficulty. Fowey Reef lies five miles from the low coral island of Soldier Key. Even in calm weather the sea is rarely quiet enough to make it safe for a vessel of any size to approach the reef. The builders erected a stout elevated wharf and storehouse on the key, and brought their men and tools to await the opportunity to dart out when the sea was at rest and begin the work of marking the reef. Before shipment, the lighthouse, which was built in the North, was set up complete from foundation to pinnacle and thoroughly tested.

At length the workmen were able to stay on the reef long enough to build a strong working-platform twelve feet above the surface of the water and set on iron-shod mangrove piles. Having established this base of operations in the enemy's domain, they lowered a heavy iron disk to the reef, and the first pile was driven through the hole at its center. Elaborate tests were made after each blow of the sledge, and the slightest deviation from the vertical was promptly rectified with block and tackle.

In two months' time, nine piles were driven ten feet into the coral rock, the workmen toiling long hours under a blistering sun. When the time came to erect the superstructure, the sea suddenly awakened, and storm followed storm, so that for weeks together no one dared venture out to the reef. The men rusted and grumbled on the narrow docks of the key, and work was finally suspended for an entire winter. At the very first attempt to make a landing in the spring, a tornado drove the vessels far out of their course. But a crew was finally placed on the working-platform, with enough food to last them several weeks, and there they stayed, suspended between the sea and the sky, until this structure, which cost one hundred and seventy-five thousand dollars, was complete.

FEATS OF MODERN RAILROAD ENGINEERING [1]

By HENRY HARRISON LEWIS

WHEN a certain transcontinental railway determined to make Puget Sound its western terminus it found the barrier of the Cascade Mountain in its path, and the problem was to pierce it. Longer tunnels had been built elsewhere, but never had one been considered in such an inaccessible region and on such a short time-limit. The railway was convinced that a man could be found who would undertake the task.

When the bids were opened the man was found. His name was Bennett, and he guaranteed to deliver the tunnel within twenty-eight months, and at a figure considerably below those of his competitors. He was derided by all save the railroad company. The company told him to go to work. It was in New York City, the 21st of January. Three thousand and odd miles away, at a spot in a region desolate and remote from civilization, a tunnel two miles in length was to be constructed in a trifle more than two years.

Bennett's first act was to telegraph an assistant in the West to gather a force at once and clear a road to get the machinery on the ground; then he purchased and shipped an equipment consisting of engines, water wheels, air-compressors, boilers, exhaust fans, two complete electric arc light plants, fully equipped machine-

[1] From "The World's Work," by permission of Doubleday, Page & Company. Copyright, 1903.

shop outfits, miles of steel rails, three dozen air drilling machines, two locomotives, two sawmills, two telephone outfits, and tons of steel drills and other supplies.

This large plant reached the end of the rails in time, and then came the question of transporting it to the scene of operation. From the end of the railroad to the mountain-side was a distance of eighty-two miles, which included a rise of thirty-seven hundred feet. For the entire distance, until the mountain range was gained, the course was over hills, through valleys, across streams, and much of the way along an untraveled route. The only means of transportation were wagons and sleds.

As an example of the difficulties Bennett and his little army confronted, for the last fifteen miles before ascending the Cascade Range the mud was so deep, as the result of a thaw, that it was impossible for the double teams to haul the wagons, which sank to the hubs in the mire. Planks had to be brought from sawmills, miles in the rear, and laid down lengthwise in front of the wheels of each wagon of the train. As fast as the train passed over the planks they were hauled to the front and laid down again. The wagons were hauled over these planks by blocks and tackle, the rope tied to the end of the wagon-tongue, and a team attached to the other end, while the men guided the wagons on the planks. By this means all the heavily loaded wagons of the train were worked along over the fifteen miles of miry road at the rate of about one mile a day.

These difficulties passed, the ascent of the mountain began and the obstacles to the journey were increased. Snow was encountered so deep that it was necessary to improvise sleds from small fir trees, and transfer the loads of heavy machinery from the wagons to these sleds. So difficult and perilous was the new road, running along

gorges five hundred to one thousand feet deep, and precipitous mountain-sides where it was impossible for the teams to haul the loads, that the blocks and tackle had to be again used for hauling. When the machinery was finally set up on the site of the tunnel, six months of the twenty-eight allowed under the contract were gone, and Bennett had expended one hundred and twenty-five thousand dollars.

There was grave need of haste, and work was carried on every day and night in the year, and at both ends of the tunnel. This required four shifts and a monthly pay-roll of thirty thousand dollars. To stimulate the work the contractor offered a bonus to the men engaged in drilling. In spite of this inducement the task proceeded slowly, and only by the greatest effort the daily average of excavation was maintained. Toward the end money flowed like water. No expense was spared. The contractor and his immediate assistants scarcely slept.

On the eighth day from the time set for completion the drilling forces in the headings met at a point about midway of the tunnel, and twenty-four hours later the excavation was at an end — just seven days before the expiration of the contract time. With all the haste and all the drawbacks, the two working forces met in the center of the two-mile-long tunnel with an error of only a fraction of an inch.

To-day there are more than two hundred thousand miles of railway tracks in this country, and each ten miles represents an engineering achievement. There are tunnels and bridges, revetments and cuts, built under all conceivable conditions and at a total cost of hundreds of millions of dollars. There does not seem to be any obstacle too great to be overcome by that little body of silent, modest, earnest workers we characterize merely as railway builders.

How many of us can call to mind the name of the engineers who projected and built that marvel of engineering, the Oroya Railroad of Peru, which reaches an elevation of more than fifteen thousand feet above sea-level, a height at which it is difficult to generate steam. The two Americans who constructed this road, Messrs. Meiggs and Thorndike, were considered crazy when they proposed it.

It was necessary to carry the roadbed for miles through galleries cut in the solid face of the rock, and the workmen engaged in cutting the galleries were in many cases lowered in cages from the cliffs above. More than sixty tunnels had to be cut in the course of construction, one the famous Galera Tunnel, one and one-half miles in length, the highest engineering project of its kind on earth.

On this road the signal achievement of constructing a lofty steel bridge connecting two tunnels was accomplished. In building this bridge, which spans a crevice five hundred and seventy-five feet wide and hundreds of feet deep, it was necessary to lower all material from the top of the cliffs by wire cables.

The whole stupendous task was made possible only by the liberal use of the " V switch " or " switchback." In one instance on the Peruvian railroad it was found necessary to construct a switchback in the side of a mountain, the train heading in on the lower level and backing out through an upper tunnel almost exactly above. The cost of the Oroya Railroad, when completed, was forty-three million dollars, or three hundred and eleven thousand five hundred and ninety-four dollars a mile, making it one of the most costly roads in existence.

The annals of railroad construction are filled with instances of unforeseen obstacles. During the construction of the Guatemala Central Railroad, which was built

by American engineers, between the port of San José on the Pacific coast to the capital of the country, Guatemala City, a distance of seventy-three miles, a broad sheet of water called Lake Amatitlan was reached. One side of the lake was mountainous and the other low-lying, but made up of very treacherous volcanic earth. It was decided to try the mountainous side first, and a tunnel was begun.

After boring a short distance, probably seven hundred or eight hundred yards, it was noticed that the temperature began to increase amazingly. Finally it became so hot in the borings that the navvies refused to continue. Then some one connected with the construction pointed out that the lake was midway between two volcanoes about twenty-five miles apart.

"There must be a subterranean connection between them," decided the chief engineer, "and we almost penetrated into one of the vents. We will try the other side." The rails were laid along a surface broken up with little steam-jet crevices until a spot was gained where the two shores of the lake were not more than a thousand feet apart. Gravel and earth were brought in quantities, and in the course of time a causeway connected the two shores.

"We will lay the rails the first thing in the morning," announced the chief engineer, when the last shovelful of earth had been thrown down. That night there was a slight earthquake shock, but as such things were not unusual nothing was thought of it. The following day at sunrise, as the chief engineer was leaving his bunk, one of his foremen rushed up in great excitement.

"The fill, sir," he cried, "it 's gone. The whole causeway has disappeared."

When the engineer reached the spot he saw nothing save the placid surface of the lake. Of the thousands of

tons of earth and rock that had been dumped into the water, not an ounce remained in sight. Soundings were made from a boat and a depth of sixty feet was reached. Sixty feet was the depth of the water before commencing the fill!

"This looks uncanny," said the engineer. "Where has all that earth gone?"

He borrowed more boats from the neighboring town of Esquintla and made a thorough sounding of that part of the lake. His efforts resulted in the discovery of a ridge extending between the two shores at the spot he had selected for the building of the causeway. It was the only shallow place in the whole body of water, and there was no other way out of it; so the filling-in process was repeated. Again the embankment disappeared, and not until the third filling had been completed, at a cost of many thousands of dollars beyond the original estimate, was a permanent way established. It still exists.

It is possible that the building of few railroads has called for greater skill than the transcontinental Canadian Pacific. The "Jaws of Death," a famous bridge on the mountain division of the road, was a triumph of that marvelous skill which makes every railroad builder an inventor when need be. The railroad had reached a spot on the Fraser River where it was necessary to skirt the edge of a rocky mountain. It was impossible to build along the top, and equally impossible, because of recurring floods, to construct on the level of the river. Only one thing was left — to cut a ledge along the face of the cliff itself. As an engineering task, this was simple enough, being merely a question of drilling and blasting, but half-way along the mountain-side was a deep cleft in the living rock which extended from the summit to the river. The

cleft was hundreds of feet wide, and almost as deep, and it presented an engineering problem that nonplussed the staff of the construction corps.

A wooden trestle was thrown across, and it fell under the weight of a construction train. Then another bridge was started, and Sir William, then plain William C. Van Horne, an American railroad builder, who had been called upon to construct the road, was sent for. He devoted a day to the problem, and then started the masonry bridge, which still endures.

Another example of ingenuity is the method adopted in replacing old wooden trestle bridges with permanent structures. In the Rocky Mountain district are numerous ravines which are spanned by trestles because of the time limit of construction, and also because of the great cost of transporting steel bridge material across the continent. When it became desirable to replace these wooden trestles, a division superintendent of the road, who was himself an engineer and who had assisted in the building of several roads, suggested filling in the most important ravines. He was laughed at.

"Why, man, it will take all the cars we have to transport the gravel, and it would cost a fortune," objected the chief engineer.

The division superintendent had worked out the problem before making his suggestion, and he quietly replied:

"It will not be necessary to haul gravel to fill up the ravines. We can get the material on the spot."

"How would you shovel it? It would take an army of men."

"It can be done with a dozen," was the division superintendent's startling reply.

After enjoying the chief engineer's expression of astonishment for a moment, he explained:

"It can be done by hydraulic power. We can take the Mountain Creek trestle, for instance. It will be a simple matter to make a temporary dam up the mountain-side and with the force of water thus obtained use a monitor on the side of the hills at each end of the trestle. The gravel can be sluiced down wooden conduits and terraced up from the bottom of the ravine. The cost will be small, and only a short bridge span will be needed."

The plan appeared so feasible that, after it had been duly considered, an appropriation was made by the Board of Directors and the work begun. It is simply another instance of ingenuity and brains properly applied.

To-day there is a road building between Chile and the Argentine Republic that possesses some very interesting points of construction. It is called the Trans-Andine Railroad, and it will extend, when completed, from Mendoza, Argentina, to a small town in Chile. In its course it will pierce the Andes by a tunnel in many ways one of the most remarkable ever built. The road, which is narrow gage, is of ordinary construction until it reaches the foot of the mountain. Then it ascends through a gorge, with the aid of a cogged rail, until it reaches the limit of elevation. Then it enters the tunnel, which by reason of a necessary sharp descent is built in spiral or corkscrew shape, crossing under itself, until the Chilian side of the Andes is reached. It is expected that the road will be ready for traffic in two years. It was begun as far back as 1887.

Mount Tamalpais has long been famous as the only lofty mountain in the immediate vicinity of San Francisco, and in time it was decided to construct a road to its summit for the benefit of pleasure seekers. No little ingenuity was necessary in solving the engineering problem to make a possible ascent, and the task was accom-

plished only by a remarkable series of long reaches and gradual ascents up the sides of the largest cañons, and finally by a succession of loops, popularly known as the bowknot. Coming up out of a cañon it has crossed, at the head, the road sweeps to the west, turns to the east, making another end to the bow, then quickly turns backward and downward to rise and complete a second bow, during which it proceeds on a regular grade to the summit, from which the traveler looks directly down upon the winding and circuitous track which has solved an exceedingly difficult problem in mountain climbing.

THE KIND OF MEN WANTED AS ELECTRICAL ENGINEERS[1]

BY W. H. BLOOD, JR.

MY subject is a serious one and admits of very few opportunities for jest or humor.

Everyone, I suppose, has in mind what an ideal electrical engineer should be, and every one of these standards, I imagine, is different. I presume that no one, however, has the same idea of an electrical engineer as an old Cape Cod character had whom I ran across a few years ago. In one of the little towns on the Cape there was an old man who, in his one-horse chaise, used to meet every single train that came into the station, and made it his business to know everyone who came into town. I had not been in the village more than a couple of days when the old man came around and called on me. He immediately asked me what my business was, and I told him that I was an electrical engineer. He said, "You be?" and I said, "Yes, I am." He replied that he supposed I had come down there for my health, and, as I was just recovering from typhoid fever, it happened to be the case, so I assented. Then he said, "I should think you would enjoy the good air down here after spending all your nights running those dynamo machines in those hot engine rooms."

You may have the same conception of an electrical engineer that this old man had, and your aim may be to take charge of an engine room full of complicated machinery; or, it may be that you aspire to be a man who, by

[1] From "The Public Service Journal." By permission of Stone & Webster.

pushing the slide rule and by using intricate formulæ, is able to figure out the most difficult electrical problems. To be a man capable of designing electrical apparatus of high efficiency, and at a low cost, may be your aim; or, possibly, you may hope to be manager of some electric light or street railway plant, giving special attention to operating details. Perhaps you intend, after some years of experience, to be a manager of managers and to have under your eyesight a group of properties successfully operating, because of your unusual ability and because you have developed the qualities which make the technical engineer an all-round, broad business man.

Regardless of the height of your aspirations, and no matter what occupation you may choose, it should be your aim to do your best — to be at the top of whatever strata you are in. A thoroughly first-class station operator is of much greater value to the community than a slipshod, careless, indifferent man, who sits in an office, regardless of the fact that a large sign in gold letters bearing the title " Electrical Engineer" may adorn your door.

The first characteristic to which I wish to call your attention is *honesty*. It goes without saying that an engineer should be honest. The first requirement of permanent success in any line of business is honesty. Above all things, the engineer must be honest with himself. The old saying that " Honesty is the best policy " is good as far as it goes. With the engineer, however, it must be the *only policy*. The engineer who is even slightly dishonest soon gets off the track, and the habit of coloring reports or statements to fit conditions quickly grows and his reputation is ruined. One of the most difficult positions in which the young engineer is placed is upon the witness stand, testifying for his client. It is so easy, in

case of exigency, to stretch the truth and say something that will help the case along. Regardless of the morals, it does not pay. The open, frank, honest engineer wins out in the long run.

From your earliest childhood you have been taught that *perseverance* was necessary for success. When you were very young, you learned that "If at first you don't succeed, you must try, try again." If you need this in school, you certainly need it in future years after you get out in the world. Success will not come easily — it requires busy days and perhaps sleepless nights. Keeping everlastingly at it, however, brings success.

Accuracy is another essential for the electrical engineer. This does not necessarily mean that in making a calculation or an estimate the figures shall be carried out to eight or ten places beyond the decimal point. The appraisal of a property which the engineer reports to be $10,437,621.17 is not accurate; it is misleading, for it tends to convey the idea of accuracy, while in reality, if the figure is within $100,000 of the actual cost it is a good estimate. For two independent engineers to get within one per cent is close figuring. The difference of one cent, however, on some transactions may mean failure or success. One cent per kilowatt-hour is a larger profit than most companies make in their electric lighting business.

The late Mr. E. H. Harriman is said to have been worth $149,137,402. The six figures near the decimal point mean nothing, yet if the railroads under his control had been able to raise their passenger rates half a cent per mile he might have amassed a fortune of double the size. The engineer must be accurate, but coupled with this he should have a comprehensive idea of the significance of figures.

In our early education too little attention is paid to arithmetic, particularly mental arithmetic — practice is

the only means of developing this faculty. I often look with admiration on the butcher's clerk who tells you with accuracy, while he is doing up the bundle, that thirteen and one-fourth pounds of beef at twenty-seven and one-half cents per pound will cost you $3.64. The ordinary engineer would, after manipulating his slide rule, give you as his opinion that it would be about $3.60, or, by figuring it out on paper, say that the answer was $3.64375.

Much of mathematics as taught is of little *direct* value in your life work. Arithmetic, as I have previously stated, you should know thoroughly; algebra is also important. Geometry and trigonometry, for some work, are essential, but you will probably feel, after you have been out a few years, that least squares, theory of electricity, calculus, etc., are of little real value. Nevertheless, the concentration of the mind which these studies require, the solving of problems, the working out of results and proving them, help you materially to get the better of more serious problems later in life when thrown upon your own responsibility.

It is not supposed that a course at a Technical School will send out finished electrical engineers. Professor Jackson, talking on technical schools, several years ago, said the schools " do not turn out finished engineers but young men with a great capacity for becoming engineers." You learn how to learn; you are taught where to find things; how to apply yourself; how to work. The foundation only is laid in your education. The structure depends upon your own ability and comes only through hard work and years of experience. Now, when you go out into the world, rest assured that you will get plenty of hard knocks. Be prepared for them. Take them as you would in a football scrimmage. They are part of the

game. Do not look for "snaps." Get your experience as early as possible. The rougher the experience and the younger you are when you get it, the more able you will be to profit by it. Theoretically, you are an electrical engineer; practically, you are not. Your training in theory which you get at school, however, will, with the practical experience which you will get outside, soon put you where you wish to be — in the great brotherhood of electrical engineers.

The curriculum at a technical school does not usually include a course in general management, but four years' contact with other men often develops *executive ability.* Football captains have to be chosen, a manager for the school paper must be secured, class officers selected. Some men are apparently born to rule. The various school organizations often bring these men to the front, and, frequently, men with only mediocre ability as scholars develop into remarkable leaders and become known as "men who can get things done." The characteristic of knowing how to rule is one greatly sought after by men in business. The man who can lead is the man who makes the success. No *one man* can do everything, but he can gather around him men of special ability, and by his greater executive ability he is able to build up a successful organization.

Alertness is another essential characteristic. To be alert and to be alive are about the same. "Dead" men have no place in this age and generation. Electrical engineers, above all, must be keen and active. Progress has been so rapid in electrical lines that the man who falls asleep finally receives some severe jolt which awakens him and he is forced to realize that the day of Rip Van Winkles is past. The aëroplane, with a dead engine, soon comes to the ground; the faster it goes, the less liable is it to

fall. The electrical engineer who does not keep up to date and does not keep his eyes and ears open soon, to use an Irish expression, "wakes up and finds himself dead."

Tact one should have, and it can be cultivated; it is not natural with most of us; it comes hard for many. It is a great temptation to say just what one thinks, but it seldom pays. Frankness, on the other hand, is an admirable quality, yet that may be carried to an extreme. I knew of a man who once made a report which was so blunt that it was brutal, and after reading it he realized that he had overdone it and apologized by saying that he believed in "calling a spade a spade." The man who received the report responded that he did not mind "calling a spade a spade," but he did not believe it was necessary to "call a spade a — shovel."

I hardly need dwell upon the subject of *loyalty*. One seldom sees an educated engineer who is not loyal. You sometimes run across an uneducated station operator, who, when he leaves his employer, tries to put wires or piping out of commission. Most engineers, however, are thoroughly loyal, and for this they are to be commended.

Engineers are not noted for fluency of speech, nor are they able, as a general rule, to write *good English*. Easy writing is an art, but not impossible of acquirement. I sometimes feel that not enough time is devoted to English composition and to the reading of standard authors. Nothing so improves one's vocabulary as reading the works of careful authors. You perhaps say that you have no time for such reading. Perhaps, if you spoke honestly, you might say that you have no inclination. How many of you have read Thackeray, Dickens, Shakespeare, Victor Hugo, Balzac?

We engineers are not broad men. We ought to be

ashamed of this, perhaps some of us are. A prominent and successful engineer said, in an address on this subject, "It is better never to have seen the inside of a Latin, French or German grammar and to use correct English, than to have the ordinary three or four years' 'translating knowledge' of all three of these foreign languages and still say, 'I seen.'" I had a classmate, a college graduate, who, when working on his thesis here, always spoke of his associate and himself as "I and Mr. Smith," very much after the order of the boy who wrote the composition on "The dog and I and father." Electrical engineers are called upon to write reports, and to say what is to be said in concise, clear English is most desirable. Truth must not be sacrificed in an endeavor to be brief, and, oftentimes, unless the whole truth is told, the impression left is ambiguous — if not misleading. To be clear, you must put yourself in the other man's place and assume that he knows nothing of the subject upon which you are reporting.

The twilight zone between *self-assurance* and conceit is very narrow, yet without the former a man always remains a drudge. The lack of this quality has often kept a man with a good education at the bottom of the ladder all his life. An educated man who starts as an engineering draftsman may, *with push,* become a manager. The man with a "swelled head," however, is a success in his own opinion only.

To succeed, the engineer must have *initiative* and must be *practical.* A dreamer may have initiative, but without the balance wheel of practicability his schemes are worth nothing.

You are all familiar with the old story of the philosopher and the goose. The philosopher had a goose which laid eggs which were worth in the market three cents

apiece. The philosopher found, after some time, that the cost of these eggs to him was four cents. Just what to do, he did not know, so he called in a friend who, being of a practical turn of mind, suggested that the goose, instead of being fed on purchased fodder, be turned out to grass, but the philosopher replied that he had no grass on which the goose could feed. The friend then suggested that the goose be killed, and the philosopher complied with the suggestion and sent word to the fodder merchant that he was that day dining on roast goose and that henceforth he need send him no fodder for the goose. The philosopher had something of an engineering turn of mind. He knew how to figure operating expenses as well as gross receipts, but he was not practical — his knowledge was of no use. The practical man had to tell him what to do.

The true engineer should not only find the cause of trouble, but should be able to suggest the remedy. Don't get into the habit of "knocking" unless you can show a better way. Practicability is a long word, but without this quality the engineer and his training go for little. Gumption, a colloquial New England word, is one phase of practicability and to me means a great deal, for often the man with gumption accomplishes things which the man with education fails to do. If you have both, you can do wonders.

The ladder of success is a long one. It is set pretty steep. Some of the rungs are broken and you may have to shin, but it reaches the top and there is plenty of room up there, so take courage, mount it, rung by rung, and join the ever-increasing group of successful electrical engineers.

WEALTH FROM AN UNDERGROUND RIVER[1]

By HAROLD DUNTON

IF he who makes two blades of grass grow where but one grew before is greater than the builder of cities, then there is a man in southern California, a pioneer of civilization along agricultural lines, who has done more than all the builders of all the cities since time began. He has made, not two blades of grass to grow in place of one, but whole alfalfa fields where there was nothing but a stretch of glaring sand; in place of sage brush and greasewood and juniper he has in successful growth orchards of apples and pears and plums; green fields of barley and corn turn to the yellow of early ripeness under his hand, and where the jack rabbit and the coyote, the crawling lizard and the hissing rattlesnake ruled the land he has set his home, carving the way for other men to come with him and share in the riches of an undiscovered farming land lying at the very doors of civilization.

The man is W. G. Dobie, a physician of ability, a globe trotter of years' experience, turned ranchman on the Mojave to prove or disprove an idea which had its origin in a casual trip across the great sand plat. This idea, which was that a great body of water, either lake or river, underlies the entire Mojave desert, he has completely proved, and he is now on the eve of reaping the rich harvest of his idea.

About one hundred miles from Los Angeles, twenty

[1] By permission of "The Technical World." Copyright, 1909.

miles beyond the eastern mouth of the Cajon Pass, the gateway to southern California, lies his ranch, seven miles from the little town of Victorville, on the Salt Lake Railroad. Behind him rises the wall of the mountains, snow-capped in winter, filled with rippling brooks of life-giving water in summer. Out from his door, beyond his green and yellow fields rolls the desert, away through the foothills, breaking into a level plain which stretches away to the east until it is lost in the blue haze of distance.

Victorville has been a town for years, noted principally for the excellent sport hunters had there shooting jack rabbits. It also has some reputation as a health resort for lung diseases, but beyond this it was a town simply because it had been a watering place on the old trail, long before the iron horse woke sleeping hills of the Cajon Pass with its siren blast.

The great West of half a century ago is no more. The West of to-day is the great, untried, little-known desert. Fertile as any of the lands on which stand California's millions of dollars' worth of orange groves, only lacking the water which has filled coastal acres with the apples of Hesperus, the Mojave Desert has shown itself a new empire, opened to settlement by the theory, the energy and the perseverance of one man.

Dr. Dobie has worked silently. When he went out to Victorville about three years ago, with his wife, his sister and a friend, who held like ideas as to water, no one knew of his going, no one was burdened with the story of his plans. To-day he has a fine home, as desert homes go, an abundant supply of water, and, stretching away to left and right of his home, well tilled fields of barley and alfalfa, with orchards of all manner of deciduous fruits.

The twentieth century pioneer took up a tract under the Desert Land Act, and then set about getting water

on it, without which he must fail in his project and lose his land as well. For years, men who have looked at the Mojave Desert have declared that it was impossible to get water on it; that there was no way by which the precious fluid could be brought from the mountains and impounded, so as to furnish irrigating water at a time when it is most needed in the summer.

More than this, they said that the places where water could be found by drilling were few and far between; that no great body of water underlay the desert; that all the hundreds of streams that rush out of the mountains to sink away in the friable soil of the plain went down so deep that they could not be reached by any manner of drilling known of man. Believing this, they turned their attention to the Colorado and other sections of the desert, letting the Mojave lie as it has lain for centuries, a useless waste of parched and arid land.

Now, Dr. Dobie had unbounded faith in his theory that there is water in a vast body under all of the Mojave Desert. During the first year, not being able to find water on the land he had taken up, the fluid was hauled from Victorville to supply himself, his family and his horses. Eventually he did find water, small in amount and brackish in taste. Then he reasoned that if this surface water underlay the desert, there should be more abundant and better water deeper down.

Men and teams and drilling outfits were brought in; one, two, three hundred feet, straight down through sand, gravel, hardpan, and finally the bed of cement which is found beneath the entire floor of the desert, until at a depth of more than three hundred feet an abundant supply of sweet, fresh water was found. In addition to his theory of the great subterranean supply, Dr. Dobie had believed there would be force enough to this confined

water to raise it to the surface in flowing wells. In this he was disappointed, but he found an endless supply of water, which could be pumped to the top of the ground.

A gasoline engine was set up, after repeated failures in the drilling, in which tools were lost, rigs blown down and holes caved in, and water enough secured for domestic purposes and for the use of the stock. But it was soon seen that the long haul by which gasoline had to be brought in for the engine precluded the possibility of using it as power to lift the water from the underground river. Soundings in the well proved it practically bottomless. The lead went down until it could no longer be controlled by the man at the surface, and was carried swiftly to one side, with a strength which the operator was scarcely able to withstand. With the greatest difficulty the cord and lead were withdrawn from the well, and the frayed condition of the cord showed that it had been rubbed on the rock roof of the subterranean channel with great force by the power of the water.

It was found necessary to adapt some other power to the pump. In this section of the desert there is a wind which blows for a time each day from a certain direction every day in the year. An ordinary windmill was erected, a mill of the most modern kind, with steel tower. The second day of its life it was blown down.

Then a squat, four-square derrick, home-made and of low height, was set up. On the top of this was set a double-power windmill, with two fourteen-foot wheels. Against this mill the desert winds exerted their utmost strength, but without avail, and to-day it is drawing from the inexhaustible supply of the underground river a man-made flood with which the grain and hay fields and the orchards of various fruits are being irrigated in as thorough a manner as are any of the orchards of the Pacific Slope.

Interesting it is to note that under analysis the waters of this hidden stream show remarkable purity and excellence for table use. The flood which pours out of the large, double-power pump is soft, clear as crystal, with a total of mineral solids of only 15.30 per cent. On the outlying sections of the large farm, in every direction from the present well, experimental holes sunk with diamond or core drills have shown the same abundance of water, indicating that the stream is of great width, probably Nature's drainage canal for the entire eastern slope of the Sierra Madres and other small ranges which wall in the desert on its western rim.

These wells are finger boards to the greatest discovery which has ever been made on the Mojave Desert. Beside their value the wealth of the Yellow Aster, the Mohawk, and all the other bonanzas which mining men have uncovered amid the low buttes of the great plain pales almost into insignificance, for Dr. Dobie has proved that this vast area of land can be converted into waving grain and hay fields and green-leafed orchards.

Three great things, great in any generation of any nation's life, this quiet, unassuming man has accomplished:

He has opened an area of thousands of acres of barren land to settlement, in which the settlers may obtain the land for a song.

He has proved that under this entire stretch of ideal farming lands there is an abundant, easily-reached supply of water, more than sufficient to irrigate all of it.

He has shown to those who may come after him how each one of them can conquer the forbidding desert; how the laborer, stifled on his forty-foot lot or in his tenement rooms, can go to the free West, and, under the finest, most healthful skies in the world, become his own landlord.

Acres on acres of the Dobie Ranch, onto which the

waters from the underground stream have not as yet been brought, are being made productive under the Campbell system of dry farming, but the return from that land which has been supplied with water is so much greater than from the dry acreage, that Dr. Dobie does not believe in toying with the latter except to fill in the time until ditches can be dug and pipes laid to carry the life-giving fluid all over the ranch.

It should be mentioned here, however, that all of the doctor's garden is cultivated on the dry land, and from it he has produced some of the finest onions and potatoes ever grown in the Southwest. Markets for all manner of garden produce are abundant on the desert, and ruling prices are high. Practically all the vegetables used in the mining camps and railroad and stage stations of the desert must be shipped in from the coast, a slow and expensive method of getting supplies.

All the long, wide slopes stretching along the mountain wall are reached from most of these towns and camps by fine roads, over which the hauling of vegetables and other garden fruits can be done without hardship to horses or men. Some of the profits in truck farming for these towns may be imagined when it is told that onions range from fifteen to twenty-five cents per bunch,— selling on the coast for five cents,— and that potatoes, worth on the coast one and one-half to two and one-half cents per pound, sell in the desert towns at five to ten cents per pound.

Deciduous fruits alone promise to be immensely profitable. Where the demand for vegetables and general farm produce is as great as it is on the desert, it is but natural that the supply of fruit is always insufficient to meet the needs of the people whose mainstay often is bacon and beans.

Apple trees, set out three years ago by Dr. Dobie, are in bloom, and give ample evidence of an abundant crop soon to come. Peach, plum, pear, apricot, cherry, white mulberry, Russian mulberry, prune, and fig trees are in excellent condition. English walnut and eucalyptus trees have been planted at a later date than the fruit trees, and give evidence of successful growth. Oranges have not been tried, but farther south, on the Colorado desert, good luck is attending those who have planted these trees around Brawley and Calexico, so that Dr. Dobie is encouraged to the belief that he can grow oranges on his desert ranch. He will experiment with various varieties this year.

Spineless cactus has shown remarkable growth at the Dobie ranch, though the first clippings were set out only a few months ago. Other varieties will be set out as fast as possible on the land above the well, where water can only be distributed with difficulty and by lifting it with force pumps. In addition to forage for cattle and horses, it is planned to try to create a demand for the fruit of the spineless cactus in the desert towns. This fruit is widely used throughout Mexico, and there Dr. Dobie received the idea of using it on the desert as a table fruit. It comes into full ripeness at a time when there is little other fruit to be had, even in sun-kissed California, and should be another wealth producer for the man who has conquered the Mojave Desert.

And who is this man? Born in Dunfermline, the native town of Andrew Carnegie, he is a Scotchman, from the top of his gray hat to the soles of his broad-toed shoes. Persistent in his ideas, determined to make his theories come true, whether fate so decrees it or no, he is a man of indomitable will and purpose. Not alone is he working for personal aggrandizement, though this is already within

his grasp, but for the good of the country and of the people who may come after him, seeking new homes.

When Dr. Dobie found, after years of the hardest kind of labor and experiment, that it was impossible to develop enough water from the surface of the ground — i. e., from the streams which, flowing out of the mountains, lose themselves in the desert — he went about on a new tack, and, still conforming to the law, brought to the surface the water which these streams buried beneath three hundred feet of earth.

In this last-named work of his lies one of his greatest gifts to the people of the nation. Hundreds, probably thousands, of poor settlers on the desert have been forced to give up their little claims because they could not meet the water development requirements of the Desert Land Act. In other words, they were unable to bring to their lands enough surface waters to insure crops. Dr. Dobie's discovery of the underground river and how to develop it has given these people a new hold on life, and he has opened the Mojave to the poor man as well as to the rich corporation — for irrigation projects cost, not hundreds of dollars, but hundreds of thousands.

On the Mojave, scarcely half a day's run from a city of three hundred thousand inhabitants, Dr. William Gowan Dobie is as much of a pioneer of a new world as were his ancestors, the Gowans of Australia, half a century ago. His achievement is of the greatest importance not alone to the Pacific Coast, but to every man and woman in the United States, because it is the opening up of a new field of endeavor, a step toward the reclaiming of vast, supposedly arid areas, which will supply the demand of the ever-increasing population of this country for independent homes.

COWBOYS OF THE SKIES[1]

By ERNEST POOLE

HE was standing out on a steel girder, with a blue-print map in his hands. He wore brown canvas trousers tucked into his boots, a grimy jumper, a shirt wide open at the throat, buckskin gloves frayed by hard use, and an old slouch hat on the back of his head. His lean, tanned face was set in a puzzled scowl as he glanced now at the map and now downward at the steel frame of the building. I came cautiously nearer, looked over, and drew quickly back, *for there was a sheer drop of five hundred feet between him and the pavement.* A gust of wind blew the map up into his face. He swore, leaned slightly out to brace himself, and impatiently struck the map open. Then he jammed his hat over his eyes and continued his looking and scowling.

This was on the thirty-fifth floor. The building, the "Metropolitan Life," was to rise fifty "tiers" in all, seven hundred feet, the highest of all the skyscraper cluster. Other Manhattan giants towered around us. To the north "The Times" building rose slender and white, the roof of the famous "Flat-iron" lay close below us, and down in the Wall Street group loomed the "Singer," forty-seven stories, the "Hudson Terminal," the "City Investing," and a score of others, the largest office buildings in the world.

From our perch the eye swept a circle some sixty miles

[1] By permission of the Author and "Everybody's Magazine." Copyright, 1908.

across, with Greater New York sprawled in the center. Northward over Harlem, the Bronx, and far up the Hudson; to the west across Jersey City and Hoboken out to the Ramapo Hills, Orange Mountain, and Newark Bay; southward down into the harbor crowded with vessels and tugs; and eastward over the end of Long Island out to the misty gray ocean, black here and there with the smoke of the ships endlessly coming and going.

Even through the noise of the wind and the steel you could hear the hum of the city below. And looking straight down through the brisk little puffs of smoke and steam, the whole mighty tangle of Manhattan Island drew close into one vivid picture: Fifth Avenue, crowded with carriages, motors, and cabs, was apparently only a few yards away from the tenement roofs, which were dotted with clothes out to dry. Police courts, churches, schools, sober old convents hedged close round with strips of green, the Tenderloin district, the Wall Street region, the Ghetto, the teeming Italian hive, lay all in a merry squeeze below: a flat, bewildering mass, streets blackened with human ants, elevated trains rushing through with a muffled roar. And from the North River a deep shaking bellow rose from the ocean liner that just at this moment was swinging out into the stream.

Down there humanity hurried and hummed. Up here the wind blew fresh and clean and the details of life dropped off into space, and above me on the open steel beams that bristled up into the heavens some two hundred grimy men clambered about. Silent men in the roar of the steel, seemingly careless and unconcerned, in this every-day job of theirs up in the skies.

Between their work and the world below are two connecting links, the blue-print map and the beam of steel.

The maps represent long months of arduous labor by

scores of engineers. First conceived as a whole by the architect, they are elaborated, enriched by his draftsmen; turned over to the building contractor, to be drawn over and over in ever-increasing detail, first floor by floor, next room by room, and finally beam by beam. There are hundreds of maps, and they bear a staggering mass of figures, intricate calculations as to the stress and strain upon every beam and rod according to "dead weight," "live weight," "impact," and "wind pressure." Here is careful figuring, checked and rechecked by many vigilant eyes. For human lives depend upon its exactness.

Meanwhile, the iron ore has been dug from the Lake Superior mines; in the Pittsburg mills it has been blasted, the white-hot ingots have been rolled out into beams and plates, and, with the blue-prints as patterns, the beams and the plates have been shaped and trimmed into columns and girders and trusses, the rivet holes punched, and the rivets welded in tight — all but those connecting the joints. And when at last the maps and the beams, the brains and the matter, come together up to the skies, the maps show exactly where each mass of steel is to be fitted and riveted into the frame.

"All we do is to put 'em together," said the man with the blue-print. "Easy as rolling off a log, only rolling off wouldn't be pleasant. Look here," he added, "here's one of the girders just starting up."

There was a creaking and straining over our heads as the ponderous derrick swung round. Its "mast" of steel was lashed by cable guys to the center of the building's frame. Every week or two, as the building rose, it had been moved farther up. From the base of the mast the steel "boom" reached upward and outward, extending some twenty feet over the cañon below; and from the boom's upper end two cables, looking like mere silken

threads but in reality one-inch ropes of woven steel, dropped five hundred feet to the pavement. Slowly the boom swung out to position, the cables grew taut and began to move. The journey had begun.

Looking over the edge I could see the girder leave the street, a twenty-ton beam that looked like a straw. Slowly, moment by moment, its size increased. Now you could see it swing slightly, and tilt. It was steadied by a guy-rope that curved out into the wind like a colossal kite-string, and far down in the street a tiny man lay on his back with the rope wrapped under his armpits. A crowd stood round with upturned faces. The journey took five minutes in all. At last the beam rose to the rough concrete floor on which we stood. There were no walls around us.

A man beside me gave a sharp jerk to the bell-rope. This rope ran thirty-five stories deep into the bowels of the building. In his closet down there the engineer jerked a lever; his engine stopped. Up here the great girder stopped and hung motionless before us. An hour before I had been down with the engineer; I had been surprised at the strained look on his face as he listened for the stroke of the gong. But I understood now. Up here we could do nothing, powerless as so many monkeys. He had to do all the moving from his closet below. And lives hung on his promptness.

Another jerk on the bell-rope, an instant's pause, then the boom swung in and the girder came toward us. Another sharp jerk, and it stopped in mid-air. A man leaned forward, took a tight grip on the cable, and stepped out on to the tilting mass. It swung out over the street. Still another jerk on the rope, and it started on up with its puny rider. He stood with feet planted firmly in the chains that wound it round, his hands on the cable, his

body swaying in easy poise. Once he glanced at his feet and the void below, then gave me a humorous wink and spat off into the universe.

For the floor two tiers above us the upright columns had already been placed, pointing straight up, silhouetted against the blue vault above. Near their tops were the "beam seats," supports into which the girder was to be fitted. More and more slowly it rose and moved into position. The signals came now in rapid succession, till at last it hung just between the two columns.

Its rider crept out to one end. He might have been a fly, for all the effect his weight had on the balance. With his left hand clinging tightly to the steel, his eyes fixed steadily straight ahead, suddenly with his right hand he reached out, seized the column, and as the girder slipped into its seat he snatched the long tapered "spud wrench" from his belt and jammed it through two rivet holes. The mass was safely anchored. Back he crept to the other end, and there the job was repeated.

The new floor, or "tier," was now started. Later, when the columns and girders were fitted together on all four sides of the building, the flimsy wooden scaffolds would go up and the riveters would begin.

These riveters were already at work on the floor just above us. Up there on a platform three feet wide was a stout, fiery little forge where the rivets were being heated white-hot. The forge-tender plunged in his long, slender tongs, pulled them out with a flaming rivet clinched in their jaws, whirled them round in two sweeping circles, let go — and the rivet went sailing a hundred feet, to be caught in a keg by a man who stood poised on a beam to receive it.

It looked easy enough. But had the catcher dodged back from the flaming thing flying into his hands, he

would have dodged all the way to the curb below. Nobody misses up here, though,— at least only once in a very long time,— and between misses nobody thinks. If men stopped to think, the accident rate would be doubled. So all is done in an easy, matter-of-fact sort of way.

Once, just as the man with the tongs had started to whirl them to toss off his missile, the man with the keg threw up his hand as a signal that he was not ready. And then, as if doing just what he had intended, the man with the tongs let the rivet fly straight up into the air with a throw so precise that a moment later it dropped toward his upturned face. Like a ball player catching a " fly," he watched it come, made a quick step aside, caught it adroitly in the jaws of his tongs, and plunged it back into the forge, just as a bit of by-play.

On the outer side of the girder to be riveted, a narrow scaffold was hung by ropes from above. On this scaffold stood a man who received with his tongs the rivet, still flaming, from the man who had caught it in the keg. A moment later he jammed it into its hole, connecting the girder with a huge column. On the inner side a third man lifted a tool called a " gun," a ponderous pneumatic hammer, the compressed air that drives it coming through a five-hundred foot hose from the world below. He held the tube firmly against his stomach, while with a deafening rat-a-tat-tat the hammer began its fierce pounding, welding the red-hot end of the rivet flat against the steel. Meanwhile, looking over the beam, I could see the man on the scaffold outside with a " Dolly bar," one end pressed on the rivet head, the other end tight against his waist. So he held the rivet in place, taking the rapid succession of shocks from the stroke of the " gun " inside, his feet braced firmly on the planks, his body bent forward to

meet the blows that were bucking him off into space. This is called " bucking up with the Dolly bar." On a three-foot scaffold out in the air!

Cowboys they are in job and in soul, these men who work on the pinnacles. Like the men on the plains, they come from all over the world. Americans, English, Irish, French-Canadians, Swedes, now and then an Italian. And in the New York gangs this year two full-blooded Indïans are at work: cool-headed and sure, a stolid pair who have little to say, climbing about on the dizzy heights, with only a glance now and then down into the tangle of civilization, into the land that once was theirs.

Some have been sailors in the past, in the days of the old sailing vessels. That was splendid training, but not half so exciting a job as this, for out on the sea a man climbs only a hundred feet or so into the rigging, and if he drops there is always the chance of falling into the waves, which are so much softer than curbstones.

" Better recruits than the sailors," said an engineer on the Singer building, " are the boys from American farms. Here is how we get 'em: A big railroad bridge is being built over a river. The boy from the farm comes to watch it. He sees the men climbing out over the water, using ropes for stair-cases, taking all kinds of daredevil risks. And pretty soon his jaws fall open, and he says to himself that this here game beats the circus all hollow.

" He ends by getting a job, an easy job at first, inshore, carrying the water-pail or shoveling sand. All this time he 's watching the circus out over the river. He watches his chance; he gets out there himself, learns how to tie ropes and to sit on air. In a few months he is one of the gang. And then good-by to the farm. It 's a roving life after that, from Maine to the Rockies. High pay, a free hand, and excitement every minute. It 's rarely you 'll

find a man on the steel who is n't glued for life to his work. It 's a kind of a passion.

"Some of our boys, bridge builders and skyscraper workers alike, are forever moving all the way from 'Frisco to New York. Often a bridge builder goes on a skyscraper job, and again it's the other way round. But the skyscraper work is the hardest, and it's getting to be more and more a trade all by itself."

Later I had a long talk with one of the men who directed the work on the "Singer."

"Cowboys," he said, "is about the right word. The more you see and hear, the better you like 'em. There's not a job from Broadway to the moon they would n't jump at. The higher it is, the windier, the more ticklish the better. The only trouble is, they take too many chances. In our firm we check 'em up as much as we can. When the Singer building was half-way up I called in the foreman.

"'Look here,' I said, 'you 've made a record job so far. Keep it up, finish it without killing a man, and it 's worth a hundred dollars. We 'll call it pay for good luck.'

"He got the money."

The danger comes not only at the spectacular moments. It is there all the time. The girders, before they are riveted tight, have a way of vibrating in a strong wind; the men walk along them as on a sidewalk, and more than one has been snapped into space. Here is a story I heard from a man on the Whitehall building, down at the tip of Manhattan:

"It happened like this: Mac had picked up a coil of rope an' t'rowed it over his shoulders an' was startin' out on a girder. This was eighteen stories up, an' the wind was blowin' guns straight in from the harbor, an' the girder wa'n't extra steady. So I yelled over to him:

"'Heigh, Mac! Why don't you coon it?' To 'coon it' is to get down on your honkeys an' straddle. But that wa'n't fast enough for Mac. He laughed kind of easy.

"'Well,' he said, 'if I go down I'll go down straight, anyhow.' An' out he walked.

"When he had about reached the middle, there come a gust of wind that had n't stopped since leavin' England. An' Mac he was top-heavy because of the rope, an' when the gust caught him he leaned 'way out into the wind to balance. So far, so good. But you see he was leanin' on the wind, an' the wind let up so unexpected he had n't time to straighten an' not a blamed thing to lean on.

"Poor old Mac. He went down straight all right, you bet."

In the same easy spirit of unconcern a man often jumps on a girder down in the street, when the foreman's back is turned, and rides on up with the load. And cables sometimes snap. In the airy regions above, when you want to come down or go up a few "tiers," it is far easier to grab a rope and slide, or go up hand over hand, than it is to go round by the ladders. Only now and then the rope is not securely tied. Up on the thirtieth floor of the "Metropolitan Life" I saw a man walk out on a plank that protruded some feet, the first plank of a scaffold to be built. He seized a rope that dangled from two floors above him, gripped it with only one hand, and then *jumped up and down* on the plank to make sure it was solid.

On the pinnacle of the Singer building a lofty steel pole was erected with a brass ball on the top. The foreman, who wanted that "hundred dollars for luck," used all the powerful words he knew to keep men from climbing up. But in vain. He could not be in all places at once, and time and again on returning he would find some

delighted man-monkey high up by the big brass ball, taking a look out to sea.

But this is only half the story. As you watch them at work on the girders, clinging to massive steel corners, perched on the tops of columns, or leaning out over the street far below, *it is not the recklessness, but the cool, steady nerve* that you notice most. Under all the apparent unconcern you can feel the endless strain. It shows in the looks of their eyes, in the lines of their faces, in the quick, sudden motions, in the slow, cat-like movements. Endlessly facing death, they are quiet and cool by long training.

Up on the " Metropolitan Life," some twenty-five tiers above the street, an enormous circle of stone was being built in as a frame for the clock. A dozen men were at work on the scaffold that hung outside, and projecting from overhead was the boom of the derrick that hoisted the massive stone blocks. Suddenly the cable caught, and the full power from the engine below was brought to bear on the derrick. All this in an instant, but in that instant somebody saw what was going to happen. With a quick, warning cry he made a leap from the planks to the solid steel beams of the building. There was a rending and tearing above, and, just as the last man leaped in to safety, the derrick crashed down, bearing with it the scaffold and part of the stone. One empty, breathless moment, then a roar from far below, and a cloud of gray dust came slowly drifting upward to the group of tiny men still clinging to the girders. For a moment longer nobody moved. Then some one broke the spell with a husky laugh, another gave an explosive halloo — and the gang set about repairing the damage.

Down in the city the evening papers ran front-page stories describing it all in vivid detail, with eloquent praise

Constructing a Cantilever Bridge

for the " hero " who, by seeing one instant ahead, had saved a dozen lives. But some days later when I went up to the scene, hero hunting, I was met with expressions of deep disgust.

" Naw," said a workman, " nothin' at all but a derrick an' a few planks an' maybe a little stone. Them fool reporters said there was ' giant blocks of it thunderin' down to the street.' " One of his eyes showed the ghost of a twinkle. " Jest to prove what liars they are, I saw that stone on the street below, an' there was n't one chunk as big as your fist — nothin' but *little* pieces . . . Hero? Hell! Was anyone killed? Naw. Then leave it alone. We don't want any heroes or hairbreadth escapes in our business. What 's the use of these yarns that get men to thinkin'? That 's what smashes their nerve! "

" Queer what nerves can do," said a man I met in a steel plant. " I used to work on skyscrapers. I fell forty feet one day, and broke a rib, but I got up and went back to the job, because I knew if I did n't tackle it then I'd likely lose my nerve for good. It's the same in the circus with the boys up on the trapezes.

" That time it worked all right. But another time, in October, when night was coming on, I stepped into the air by mistake. I only fell about twenty feet then — down a shaft — but I broke a leg, so I could n't go back up. And besides, the way it happened, unexpected-like in the dark, kind of got me. Anyhow, when at last the hospital let me out I came back to the job, they had got to the fifteenth floor, and I was worse than a baby. I had no head at all. Twice I came within an ace of getting killed. At last I just missed killing one of the gang. And then I quit. Nerves is a mighty queer thing. You can shut yer teeth as tight as you please. No use.

Nerves, you can feel 'em by hundreds from head to toe, all pulling tight. And then it 's time to knock off fer good."

" Here 's one thing you want to remember," said a foreman I talked with. " You climb up to the thirtieth tier and it strikes you all in a heap. You feel kind of worried over your health, and you forget that these boys have been rising tier by tier, getting used to it week by week. The thing that I hate worse 'n poison is to take on a new man when we 're near the top.

" Speaking of new men," he went on, with a twinkle, " comical things happen even up here, the same as in a theayter. Sometimes in rush seasons there ain't enough hands to go round, and we have to take 'em green as the hills. I had one once, a kid from Vermont, a whale of a kid, with bones like a horse and eyes awful anxious to please — eyes that made you like him. He 's one of the best men I 've got now, but then he was green as God made him." The foreman stopped to chuckle.

" ' Go up to the eighteenth floor,' I told him one day, ' and bring down an old man.' I was busy at the time, and when I saw the kid stare, I said kind of sharp that if that old man was n't here in five minutes the whole blamed building would probably go to smash. This was just my way of making him hustle, but he thought I meant it word for word. He went up on the run, and in a few minutes he came down with a sputtering, clawing old feller held like a vise in his arms.

" ' He was the only old man on the floor,' said the kid. ' And he wanted to stop and argue about it, but from what you said I knew what it meant, so I just grabbed him and came.'

" You see," the foreman added kindly, noting my puzzled expression, " an old man happens to be the name of a tool we use."

These airy crews are a generous crowd. They earn high pay. When working full time they make twenty-seven dollars a week, and, like their rough brothers out on the plains, they are quick to give of their earnings. On Saturday afternoons when they line up at the pay window, the Sisters of Charity are always there, and quarters and dimes jingle merrily into their little tin boxes.

Behind this generous giving is a superstitious belief that amid risks like these it is well to propitiate Fate all you can. For Fate is a relentless old machine, and when once its wheels begin grinding, no power on earth can stop them. The "Rule of Three" is centuries old. You may hear of it out on the ocean, in the steel mills, in the railroad camps, and down in the mines. And you find it up here on the jobs in the skies.

While I was up on the "Metropolitan Life," twenty-five stories below us the offices were already completed, the business firms were moving in. In the floors between worked over a thousand men of a score of trades. But the men on the top looked down on these others as cattle-men out on the plains might look upon butchers and tanners. For only on top were the "real jobs," the jobs in the world's open places: riveting tight the mighty trusses and girders and beams, the whole "backbone" of the building, which reaches down unseen, seven hundred feet to the ground below, and far under the ground to the concrete base and the anchor rods that hold it firm to the solid rock of Manhattan.

Rough pioneers are these men of the steel, pushing each year their frontier line up toward the clouds. Wanderers, living for their jobs alone. Reckless, generous, cool-headed, brave, shaken only by that grim power of Fate, living their lives out fast and free — the cowboys of the skies.

THE SKILLED MECHANIC[1]

By NATHANIEL C. FOWLER, Jr.

THE term "skilled" or "skillful" may be so broadly defined as to cover all handwork requiring more than the exercise of automatic action, and it may be so narrowed as to eliminate any work save that of extraordinary, or, at least, of more than ordinary mechanical ability.

For the sake of convenience, I propose to consider all hand workers whose employment demands the use of their brain at the same time as they exercise their muscles. Such men may be classified as brain-and-hand workers, or as hand-and-brain workers; in the one case the brain doing more than the hand; and in the other, the hand accomplishing more than half of the work.

The expert worker is commercially one grade above the skilled mechanic; by the combination of ability and experience, he does some particular kind of work better than it can be executed by the so-called skilled workman.

Neither the skilled mechanic nor the expert worker, nor any one who employs both brain and hands, can be classed as a laborer, or as a mechanic in a purely mechanical sense.

While by the false ethics of an artificial society the skilled mechanic and the majority of expert workmen are not considered the social equals of successful workers in some other callings, they are recognized at their full worth by the representatives of civilized society. And this recognition is advancing in mighty strides, and

[1] From "Starting in Life." Copyright, 1906, Little, Brown & Company.

sooner or later the combination of brain-and-hand work will rank so high that society will dare file no exceptions to it.

The skilled workman is a product of civilization, and progress in no small measure depends upon the work of his brain and of his hand. He is a builder of something, a maker of the tangible.

The institute of technology and the technical school are to-day more vigorously pushing progress than are many of our classical institutions which teach less of the necessities and the realities of life.

The bright, capable workman, with a fair education, does not permanently remain at a standstill in any department of mechanics, unless, in spite of his mechanical ingenuity and capacity, he completely lacks ambition — a condition which too often exists. Sooner or later he may become a foreman or superintendent, and possibly a manufacturer.

The boy without pronounced business or professional capacity stands a better chance of success, both in the present and for the future, by entering some trade which allows his hand to do his hand's best, than by taking chances with what he is probably unfitted for.

If his mind takes little thought of what his hand is doing, an ordinary mechanic he will remain; but if the work of his hand comes under the intelligent direction of his brain, then he will rise as high as his combination of brain and hand will allow, which may be only a few steps above the ordinary, or to any height, even to that of manufacturer and proprietor.

The ordinary mechanic, above the laborer grade and beyond the apprenticeship step, earns from ten to twelve dollars a week on an average, and up to four dollars a day as a maximum.

The skilled workman, who is able to do something beyond mere handwork, seldom receives less than three dollars a day, and from that up to seven dollars a day.

The expert workman often earns as much as two thousand dollars a year, and from that up to five thousand a year, although comparatively few receive the latter amount. His average income is probably not in excess of fifteen hundred dollars, although there are by no means a small number earning as much as twenty-five hundred dollars a year.

The foreman and superintendent, who are either skilled workmen or expert workers, and who are disciplinarians as well as mechanics, are seldom paid less than a thousand dollars a year, the maximum being not far from ten thousand dollars, and the average from twelve hundred to fifteen hundred dollars a year.

The terms "foreman" and "superintendent" are, to an extent, analogous, and frequently both offices are vested in one person; but the superintendent outranks the foreman, the latter being usually in charge of a department, while the superintendent is manager of several departments, and has general oversight of the foremen.

Skilled workmen are usually in demand, and are seldom out of work for more than a limited period. They are not so likely to be affected by depressions in business as are those of ordinary capacity.

Expert workmen represent the highest class of handworking mechanics, and often grade with foremen and superintendents.

The man at the top, no matter what his calling may be, is a man of mark. The best shoemaker in town is not often out of work. The best blacksmith has about all he can do. The well-informed and reliable engineer

works on full time. He knows something, and if that something be a commodity, he is likely to be busy year in and year out, and his earnings will give him all of the necessities and many of the comforts of life.

Electricians as a class are well paid, because there some expertness is required, and good electricians must not only be first-class mechanics, but must understand the principles of electricity. To an extent, at least, they are expert workers.

The railroad engineer is a machinist, but he is classed above the ordinary mechanic. He is a man of nerve, of character, of presence of mind, of discretion, and able to meet emergencies. Without an abundance of qualities beyond those of mechanical ability he would not be able successfully to hold the throttle of a freight locomotive.

While shrewdness in business pays better than skill in mechanics, and while this business quality undoubtedly wins a greater money return than does any work of hand or of intellect, yet the skilled workman is not without opportunity for rapid advancement. He is in no sense a second factor in civilization.

The quality of skilled labor is rapidly growing better, and is progressing by such gigantic strides that it is only a question of time when the intelligent work of the hand will be considered upon the same plane as is the work of the brain, and there will be no such thing as despised labor. There will be little labor that involves muscle alone.

Comparatively few educational authorities, or those who have given educational ways and means intelligent thought, are in favor of a college education for those who propose to enter a mechanical trade; but the educational opinion is almost unanimous in advising, for any one who intends to be more than a common laborer, a

course in the technical school or institute of technology, or at least a course in manual training.

The boy who enters a trade without at least a partial technical education is liable to stay near the bottom or to rise very slowly; while the technical school-trained boy usually makes rapid advances after his first year at work.

Of course experience teaches, but experience is often too far away properly to instruct in the preliminaries.

A few years given to hard technical study in a good trade school or institute of technology will pay better in the end than can any amount of working experience.

But, on the other hand, technical education without experience is well-nigh worthless.

Experience without technical education is worth something. The combination of the two wins success.

A thorough technical education, with experience, never allows its possessor to remain at a standstill. He must rise, and generally rises rapidly.

No boy should begin to learn a trade, unless poverty requires it, until he has received a good common-school education; and, if possible, he should enter some technical school to be scientifically trained for his work.

Time spent in a technical school is not wasted; it pays. Perhaps not during the first year of active work, but during the second year, its advantages will permanently appear. The well-educated hand worker is sure to outstrip the untrained workman. It is a fact that few well-educated and well-trained mechanics remain in the rear ranks, and that most of them are either front-rank workmen or are promoted to command.

Let us take two boys of equal capacity and of equal trade opportunity. One spends, say three years, in the technical school, and the other enters the shop immedi-

ately after graduation from the common school. The latter boy has three years trade start of the other. At the end of three years the first boy, educated and school-trained for his work, enters the same shop. In shop experience he is three years behind the other, and for one or two years the untrained and unskilled boy may be his superior; but at the end of five years the boy especially trained, with a solid technical education back of him, will outstrip the untrained boy two to one, all things being equal.

Education fits for experience. Experience seldom takes the place of education, and when it does, it does so at the expense of the individual.

One's earlier years are, by nature and by convenience, an absorbent and educational period, in which it is natural and easy for him to enjoy school study, and to acquire the knowledge which should precede actual experience.

The first few years of technical school training give a foundation which the actual work in the shop cannot afford.

Experience needs education for its economical development.

The scientific or technical school disciplines the boy's mind, and gives him, in the most economical way, the broad principles of mechanics — the principles which experience teaches more slowly.

Too much cannot be said to impress the would-be skilled mechanic with the enormous advantage of a technical education, to be obtained in some high-grade institution where the principles of mechanics are broadly taught.

The graduate of the polytechnic institute, or other technical school, will find his diploma the key to a position.

It should be clearly understood that education, in itself,

will not produce the skilled workman or expert hand worker. Education, to be of any use, must have something to work upon — some natural ability in the first place. Without this basic material the most liberal education is worthless, and certainly has no commercial value.

The boy of natural capacity, with a willingness to work and an ambition to amount to something, finds that his education makes it much easier for him to market his ability; and, further, it enables him to develop much more rapidly than he could hope to do if he entered the shop directly from the common school.

The man is made from the boy, not the boy from the man. As the crude boy is shaped, so is the man likely to be. Therefore the boy's educational years will probably be the most important ones of his whole life.

The world needs more skilled workmen and expert hand workers. There is room for many more than are now available. These men, far more than the business men, are the pushers of progress. They, with the farmer, are producers of material commodities. They actually do something — something which contributes to the roundness and wholeness of life.

There is a superficiality to some lines of business, and even the professional, expert though he may be, to an extent handles the intangible; but the skilled workman and expert worker are natural producers of actualities — indispensable necessities in the world at large.

All skilled workmen and expert workmen were ambitious men or boys. If they had not been ambitious, their brains would not have sufficiently coöperated with their hands in making their handwork more than the result of automatic labor. Every one of them expected to rise,

either to become a pronounced success, that he might give his entire time to headwork, or to become a foreman or a superintendent, and to enjoy still further the fruits of prosperity.

A liberal technical education is an asset: first, because it assists in developing ambition; secondly, because it broadens the mind and makes it adaptable to the work of both the mind and the hand; thirdly, it disciplines the mind, that the mind may the more master the muscle; fourthly, it opens opportunity for advancement; fifthly, it is economical, because it enables the boy to accomplish more in a given time, after he is fairly started in his work, than he could possibly effect without this education; sixthly, it fits him for proprietorship.

The blacksmith, unless he is self-taught at an expense far greater in the aggregate than is the cost of being school-taught, is many times more likely to remain a journeyman blacksmith than is his neighbor who has had the advantage of some sort of technical education. This school-trained man will not long remain at the anvil. In time he will be master of many anvils and of anvil men. True, he may rise to proprietorship without the aid of the technical school, but he will be promoted quicker with this school-taught education, and can hold his own better than he can hope to do otherwise. This argument applies to other mechanical departments much more than it does to blacksmithing.

It is simply a question of going to one's work before the mind and hand are economically and practically trained, or of going at it with mind and hand especially trained and disciplined to do that work in the most economical and satisfactory manner.

I am not unfamiliar with the criticism, which is sometimes merited, that the technical school-taught boy leaves

the institute with a head out of proportion to his body, and considers himself superior to manual labor. Undoubtedly this is the case in some instances; but if the boy has the right stuff in him, this big-headness is only a transient affliction, and will do but temporary harm.

The technical school never made a wise man out of a fool, never made a mechanical genius out of a boy who could not saw a board straight, and never will. It simply gives the boy of parts a better opportunity to use what is in him. That is all it can do, and that is all it should do. It is the boy's business to do the rest.

The more thorough the preparation, the greater the chance of success.

The rapid increase in manual-training schools in our cities and larger towns has done much properly to fit our boys, and especially our poor boys, for lucrative positions. School boards all over the country, and even in some of the smaller towns, are beginning to appreciate the usefulness of the technical school, and are establishing manual-training schools or classes. Not a few of our manufacturing establishments are supporting training schools where the sons of workmen are educated free of charge, or at nominal cost.

The future of American manufactures is, to a large extent, vested in the manual-training and technical school of to-day.

America can not hold the position she has worked so hard to obtain unless she does more than she ever has done before to educate the young in technical matters.

Within the next few years I expect to see a technical or manual-training school located in every country center as a part of the educational system.

What we have to do we must do; but let us prepare for what we have to do, so that what we have to do

may be accomplished at the minimum of exhaustion and at the maximum of effectiveness.

There's economy in preparation.

Charles W. Parmenter, Ph.D., head master of the Mechanic Arts High School, of Boston, in a letter to the author, says:

"You have asked me to reply to the following questions:

"'If you advised a boy to become a skilled mechanic, why would you do so? What are the principal advantages to this calling?'

"'If you advised a boy not to become a skilled mechanic, why would you do so? What are the principal disadvantages to this calling?'

"At the outset, my viewpoint should be clearly understood. Your questions presuppose that I have had exceptional opportunities to judge of the relative advantages and disadvantages of the life of a skilled mechanic because I have charge of the Mechanic Arts High School. This presupposition is, in a large measure, erroneous. The school treats the mechanic arts as educational factors just as it deals with algebra, geometry, or French. The training which it gives is not less valuable to a boy who is to become a lawyer or a physician than to one who is to superintend a manufacturing establishment or work at the bench. The systematic study of the elements of the mechanic arts tends not only to develop manual skill, but also most valuable mental traits; for success in the school shops is impossible without forethought, perseverance, industry, and unceasing care. No shams go undetected. The boy who is not absolutely honest in his work is doomed to failure. Although the school does not aim directly to train boys to become skilled mechanics, the education which it gives often proves a stepping-stone to profitable employment in mechanical pursuits.

"Your questions also appear to presuppose that many boys will be aided by advice framed with reference to a typical boy. This is by no means certain. The fact is that the typical boy is a myth. Before helpful advice can be given, it is necessary to discover and take into account the native ability, tastes, aptitudes, and dominant powers and faculties of the particular boy to be aided. If a boy's native aptitudes and tastes incline him to a mechanical pursuit, I do not hesitate to advise him to become a skilled mechanic. Unless exceptionally favored, he can not expect to acquire a large fortune, but if reliable, temperate, industrious, and really skillful, he will be sure of a fair income and be likely to lead a contented and happy life.

"The conditions under which many skilled mechanics work are far better calculated to preserve health and prolong life than the surroundings of most persons engaged in purely mercantile pursuits. The skilled mechanic escapes in large measure the nervous strain which destroys so many men in business or professional life.

"The fundamental conditions which should determine the career of every boy are his education, native ability, and inclinations.

"That school is best which does most to reveal to boys their dominant powers and lead them to a happy choice of occupation, and that advice is best which does most to encourage them to become earnest, honest, efficient, and reliable men in the field of activity for which they are by nature best fitted.

"The most deplorable failures in life have resulted from the strenuous efforts of parents to fit their sons for careers for which they had no native gifts."

Mr. Joseph W. Phinney, manager of the American Type Founders' Company, of Boston, in a letter to the author, says:

"If I advised a boy to become a skilled mechanic instead of entering business, what would be my reason for so doing?

"I should only so advise when satisfied that the boy's desire to learn a trade was prompted by a natural aptitude and liking for mechanics; understanding this fact, and knowing the trade that he had the most decided leaning towards, I should then urge upon him a thorough theoretical and practical training, a training that ought to make him an expert, a first-class workman, and one that should command the very best consideration in position and wages.

"The same methods would obtain in advising a boy to take up business.

"As to the particular advantages and disadvantages in becoming a skilled mechanic, I do not know of any disadvantages where the boy has a natural and proper desire for mechanics. Under these circumstances he will make a much larger success in the work for which he has an aptitude than if forced into a work toward which he must always feel indifferent or antagonistic.

"It is simply avoiding the misfit of the square peg in the round hole."

THE LUCIN CUT-OFF[1]

By OSCAR KING DAVIS

WHEN the first survey of the Union Pacific Railroad came out of the mouth of Weber Cañon, a little southeast of the present city of Ogden, it found the Great Salt Lake lying across its path westward to a junction with the Central Pacific. Even at that early date some idea of the possibilities of the later-day triumphs of railroad construction seems to have occurred to the engineers of the survey, for they discussed a little, though perhaps more jocularly than seriously, the feasibility of driving straight across the lake, or at least across its eastern arm. Of course they gave it up. The idea then was almost chimerical. There was neither the genius in finance bold enough to undertake such a stupendous work, nor the traffic to warrant such an expenditure. It may be doubted, too, if there was engineering faith equal to the task. So the line was built up through the hills around the north end of the lake.

But that light talk of the early sixties was not without its fruit. The idea remained the dream, the hope, the faith, of one of the young men employed in building the Central Pacific. William Hood was of that company of "across the isthmus" pioneers who have made their mark and their fame in the development of California and the Pacific slope. As he worked his way up to the responsible post of chief engineer of the Southern Pacific

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system, owner of the old Central Pacific, he never lost sight of the possibility of that line across Salt Lake.

Collis P. Huntington, the master of the Pacific railroads, was inclined to think that it might be done; but the time was not as yet ripe, the traffic was not heavy enough to justify the expense, and such enterprises were not easy to finance. But after Mr. Huntington's death there came to the head of Southern Pacific affairs a man whose financial ability and boldness matched the engineering skill and pluck of Mr. Hood. In Edward H. Harriman Mr. Hood found a man who sympathized with and believed in his plans, and who was able and willing to provide the money.

The times had changed. The day of great and bold enterprises had come. The old era of pinching and often false economy that let roadbed and rolling stock run down in order to squeeze out an unjustified dividend, was ended. The condition had been reached where it was only necessary for the engineer to show how the interest on the investment could be made, to be told to go ahead. Traffic had increased to such a point that operation over the steep and crooked old line was becoming constantly more and more vexatious and difficult. Relief must be had.

Financier agreed with engineer as to how it could be obtained, and the result is the "Lucin Cut-off," as it is called, the line that runs from Ogden straight over Great Salt Lake, which it crosses on a trestle nearly twelve miles long and on twenty miles of "fill," and over the desert flats, one hundred and two miles in all, to Lucin, where it rejoins the old road. It is a "cut-off" indeed. Forty-three miles in distance are lopped off, heartbreaking grades avoided, curves eliminated, hours of time in transit saved, and untold worry and vexation prevented, at the

same time that expenses of operation are reduced more than enough to pay interest on the whole cost twice over.

The line around the north end of the lake had two stretches especially difficult to operate, one about Promontory, where it crossed the range of that name, and the other near Kelton, where it traversed a spur of the Hogup Mountains. At one the rise was seven hundred feet in a little more than eleven miles, at the other five hundred feet in five and a half miles. As you look at it on the map the Great Salt Lake appears something like a baseball catcher's left-hand glove, back up. Thumb and fingers are separated by the southern extension of the Promontory Mountains. Bear River flows into the eastern, or thumb, arm at its northern end.

A line along the northern shore was out of the question, because of the extreme irregularity of the land. The first survey had discussed the proposition of building across the eastern arm to Promontory Point and then following the north-shore line around the western arm; but that, too, had been rejected as not feasible, owing to the character of the country to be traversed. As soon as there was talk of rectification of the old line, both these propositions found new advocates, and at the same time the people of Salt Lake City, who had always felt a little aggrieved that the road went to Ogden instead of to their town, came forward with a proposition for a line around the southern end of the lake.

Long before the decision was made to build the Lucin Cut-off, Mr. Hood had satisfied himself as to the conditions which would have to be met. He had considered all the other plans, as well as that of a line straight across. The old objections to the northern proposals still held good. The southern route would meet many of the obstacles of the cut-off and would increase the mileage

instead of shortening it. The more he studied the whole situation the more firmly convinced he became of the feasibility and advisability of the straight line. He made repeated examinations of the bottom of the lake, by borings and soundings, and sometimes by driving pipes which brought up a core showing exactly what there was under the heavy salt water.

It was found that there was a crust of salt, soda, and gypsum overlying the mud. The layers of these different salts varied in thickness and evenness, but in general the crust seemed strong enough to withstand the strain to be put upon it. Moreover, it was steadily increasing through the regular precipitation which takes place during cold weather. It has been observed that in summer the percentage of these salts held in solution in the lake runs up to twenty-three; but with each winter there is a precipitation which reduces the percentage by spring to nineteen or eighteen.

Pending the acceptation of Mr. Hood's plans, several examinations of the bottom of Salt Lake, and of the general conditions, were made by other experts. But the fact that most of their reports were adverse, on the ground that the difficulties of construction were too great, did not convince him that he was wrong. In fact, the lively opposition that developed seemed only to strengthen his conviction.

The experts were not the only ones who were against him. Railroad men, especially in the operating department, declared that the plan was not practical. There was the likelihood of blocks on the track to be considered, and the danger of accidents, of wrecks which might seriously damage or even destroy part of the work. Salt Lake is at times subject to very severe storms. Its water is extremely heavy. The waves rise to a considerable

height and pound with great force. It was urged that they would seriously endanger the stability of trestles, and be certain to cause heavy damage to fills by washing away the material of the enbankment. The tradition of the natives was against the plan. They shook their heads and told stories of how boats had been hammered to the bottom or covered with soda by the spray until they sank under its weight. It was even advanced seriously as an argument that the terrific winds which sometimes sweep across the lake would be liable to blow trains bodily from the track into the water.

In the long list of objections, serious and trivial, there were many things to give pause to a man who was contemplating, as was Mr. Harriman, the expenditure of the millions the cut-off would cost. But it is a curious fact that of all these arguments not one has been justified by the event. There has been no damage to trestles by waves, and only a slight wash on the enbankment — never large enough to cause anxiety. Winds blow and blow without causing a tremor in the cars.

Frequent and long sidings — there are twenty-two stations in the hundred and two miles, each with more than a mile of sidetrack — make blocks impossible. Strict regulations as to speed limit, keeping trains always under full control, and careful inspection of cars before taking the cut-off, minimize the liability to wreck, and virtually eliminate the danger of serious accident. Not a prophesied mishap has occurred, perhaps because to be prophesied meant that it could be foreseen and provided against.

The only difficulty out of the ordinary which did occur, and the only one which retarded or threatened the work, was one which no man foresaw, or, in fact, could have prevented if he had foreseen. It was big enough to make

up for the absence of all the others, but it was that very one which made the construction of the cut-off the remarkable work that it is, which brought out a wonderful demonstration of Anglo-Saxon grit and persistency, and which at length put the feather in the cap of the successful engineers. That difficulty was the tendency of the bottom of the lake to leave its abiding place of centuries and seek a lower level, to the disastrous undoing of the plans and labor of the builders.

The air line of the cut-off crosses the alluvial bottom west of Ogden to Weber River and the salt mud flats to the lake, skirts the tip of Promontory Point, passes between Strong's Knob and the northern spur of the Lakeside Mountains on the western side of the lake, and then strikes across the dreary levels of the Great Salt Lake Desert, passing between the Hogup Mountains on the north and the Newfoundland Mountains on the south. From shore to shore of the lake it is thirty-two miles.

Nothing like this cut-off had ever been undertaken by railroad builders, and Mr. Hood had no precedents for guides. It is true that there are long fills on some of the Pacific-coast lines of the Southern Pacific, notably in the swampy stretch between Suisun and Benicia, and there are long trestles in the bayous of Louisiana, but in neither case are the conditions like those met at Salt Lake. Mr. Hood proposed to construct the cut-off by fill as far as possible, making an embankment which should give a permanent, solid way. Through the deepest part of the lake he planned to trestle. Both operations are in themselves comparatively simple. There is nothing spectacular about the cut-off, unless, indeed, it be the extraordinary length of the trestle. Very many pieces of engineering in mountain construction are vastly more

wonderful in appearance, though probably much less difficult to accomplish.

In the latter part of 1901 a general rectification of the line of the Central Pacific from Ogden to Reno, Nevada, was determined upon to cut out distance, reduce grades, and eliminate curves. The Lucin Cut-off was by far the greater part of that undertaking. From the nature of the work it had to be done by company forces. No contractor had the knowledge upon which to bid, or the equipment to do the work if he had known exactly what he would meet. Nor would it have paid a contractor to purchase the equipment. Certain parts of the grading, from Ogden westward to near the lake shore, and from Lucin eastward across the desert, were let to contractors, but there were parts even of this which the company had to take in hand itself.

Before the authorization to go ahead with the cut-off was given, a vast amount of preliminary work had been accomplished in Mr. Hood's office in the way of estimates of material and equipment necessary for the undertaking, and after the word was finally given, on November 22, 1901, it was some time before the actual work of construction could begin. The survey of the line had been virtually completed. It was necessary only to confirm it. But a tremendous amount of material had to be collected.

The plans provided for a permanent trestle about eleven miles long — it is nearly twelve as completed — across the western arm of the lake, over water averaging about thirty feet in depth. In the construction of that trestle, piling one hundred and twenty-five feet long was to be used. In the main roadway bents were to be of five piles, at sidings of nine. These bents are fifteen feet apart, so that something like twenty-five thousand of these huge

piles had to be obtained. They were mostly Oregon fir, and cost, delivered at the lakeside, about sixty dollars apiece.

But there was also a temporary trestle to be built — many miles of it. In constructing the fill, a trestle was first made, on which a track was laid. Over this track trains loaded with rock and gravel for the fill were run out and dumped. In the shallower places this temporary trestle was of forty-foot piles, but in the deeper water approaching the permanent trestle seventy-foot piles were used. In the temporary trestle only four piles were driven in a bent, but the bents were the same distance apart as in the permanent trestle. Thus for the two trestles a perfect forest of piles was needed. The agent of the Southern Pacific scoured the great timber districts of the country, and trainload after trainload of the huge timbers was headed toward the Great Salt Lake.

And piling was far from all. There were the big stringers and caps for both permanent and temporary trestles, and besides all the rest, though a bagatelle compared with it, timber for stations, boarding houses, and sidings, guard rails, and even a steamboat. For the construction of the Lucin Cut-off developed a new rule of railroad building — first get your steamer.

To place all these piles in position there must be drivers, and since the work was to be put through with all speed, they must be numerous. So while the tall, straight trunks were falling in the forests of Oregon, Michigan, and Texas, or trundling on their long journey to Salt Lake, twenty-five huge pile drivers were building in San Francisco, at a cost of several thousand dollars each, for the same destination. As fast as they were ready they were shipped out, in sections, to Ogden, whence, as soon as the temporary track to the lake was completed, they were hauled

out and put up. Each hammer weighed thirty-two hundred pounds.

Material for the fill was everywhere at hand. At Little Mountain, on the eastern shore of the lake, at Promontory Point, at Lakeside, on the western bank, and at Hogup, the southern end of the Hogup Mountains, gravel pits and quarries were opened, whence rock and gravel enough to turn Salt Lake into a stoneyard were easily obtainable. To transport this material to the point where it was to be used, four hundred great steel side-dump cars were built, each with a capacity of one hundred and ten thousand pounds, which in practice was often made fifty thousand pounds greater, and each at a cost of fifteen hundred dollars.

But these were not enough. All the dump cars belonging to the company that could possibly be spared from other work were brought to the task, and every road in the country that had such equipment was called on to lend or sell to the Southern Pacific. Even ordinary flat cars were used, and when all were at length collected, they numbered between eight hundred and a thousand. Eighty locomotives, great and small, furnished the motive power to handle them, and it takes a powerful engine to haul a train of twenty or twenty-five of those great steel cars, each loaded with from sixty to seventy tons of rock and gravel. Eight great steam shovels, with dippers of five cubic yards' capacity, were provided, at a cost of more than ten thousand dollars each, to dig the material out of the banks and to load it into the dump cars.

To handle all this equipment, a small army of men was required. They were gathered from the four quarters of the country, attracted by the prospect of long, steady work at good wages. If some of them found it longer and steadier than they had expected, with less amusement and

roistering for interruptions, they had only to go away. Others were ready to take their places. They got from two dollars a day, for the unskilled labor of the gravel pits and dump trains, to four and four and a half, for the skilled mechanics, carpenters, bridge workers, and engineers.

In February, 1902, the contractors began their grading across the flats at the east and west ends of the cut-off. Material was already pouring in, and by March the company forces took hold. The first thing was to get a track out to the lake from Ogden. Salt Lake is not so big as it used to be. In the last twelve years the water has receded eight or ten feet, and there is talk that it is drying up. There are those, however, who believe that it will rise again, and, in fact, that is what it does after a winter of particularly heavy snowfall or a very wet spring. The possibility that it would do that and submerge embankment and trestle was one of the arguments against the cut-off. The recession of the last ten years has left a strip of mud nearly three miles wide along the eastern shore, and when the contractors struck that they gave up. They could not grade over it. It is ten feet or more thick, and is covered with a crust of salt.

The company force that took hold laid down long planks on this mud and covered them with hundred-pound bags of sand. On these heavy cross timbers were laid, over which stringers were placed which carried a temporary track. On this the material trains were run out, the cars loaded with rock and shale, and thus the permanent way was built up.

As soon as the temporary track reached the water, the first of the pile drivers was sent out and put up. The very first work it did was to drive the piles for a steamboat slip and landing, and the building of the steamer *Promontory* was begun, a vessel one hundred and twenty-seven

feet long, twenty-two feet wide, and only eighteen inches draft. She was to be the general tender for all the work in the lake, to take stores and water to the different stations, and to fetch and carry wherever useful, the indispensable auxiliary always.

While this supply vessel was building, the rest of the pile drivers were set up, and piles were brought out and dumped into the lake. Booms were constructed to hold them at different places, whence they could be towed by launches to the spot where they were needed. As fast as the pile drivers were ready, they were set to work. A station was erected at each mile-end of the projected road. There two pile drivers went to work back to back, driving away from each other. Five bents of five piles each, or seventy-five feet in all, was a good day's work.

At each station a boarding house was built on a platform raised on piles well out of the way of storm waves. There the men lived until their work was finished. The company furnished supplies and cooks, and the men paid four dollars a week for their board. They worked in ten-hour shifts, day and night, Sundays and holidays.

It was not a very exciting life, but it was frugal and thrifty. There was not much to do but work and sleep, and there was no place to spend money. No liquor was allowed. All stores and all packages coming out to workmen were carefully searched, and any liquor found was promptly confiscated. From first to last two car loads were taken in this way. The company was in a hurry, and it could not afford to have the work interrupted by drunkenness or sprees, to say nothing of the rows and fights inevitable if liquor were in camp.

It was not so easy to keep it out on the fills as on the trestles. Two or three times squatters came down on government land adjoining parts of the right of way and

set up groggeries. Usually it was not much trouble to drive them away, but one fellow who set up shop near Hogup determined to brazen it out. However, when one of the engineers took a gang of men to his place and began to drill holes under his shanty preparatory to blowing it up with giant powder, his courage oozed, and he fled.

"He surely would have been blown up," said one of the engineers in telling about it.

Assuredly so. It would have been cheaper to pay the damages than to have the trouble-maker let loose among the men.

With the single exception of the channel of Bear River, the eastern arm of the lake is crossed on a fill. The temporary track for making this fill was carried on sandbags out into the lake until a depth of four feet was reached. There the temporary trestle began.

Great differences were found in the bottom. Sometimes the crust would be of almost solid gypsum, so hard that the huge hammers of the pile drivers could not force a timber through, and it had to be cut out with a steam jet. The first pile driven for the temporary trestle in the old Bear River bed, however, did not meet such resistance. It went out of sight at the first blow. Another was set up on the end of the first, and that, too, disappeared with one smash of the great weight. Then two piles were tied, braced and capped, and driven together. They held.

Investigation showed that the bottom, for a depth of more than fifty feet, was soft mud. In the hundred-foot channel of Bear River, however, where the ten feet of water flows with a swift current, a solid hardpan bottom was found on which to erect the permanent trestle.

In the western arm, where the piles of the temporary trestle were seventy feet long, often a blow of the hammer would sink a pile only an inch or two, although at times it

would go down as many feet. Sometimes when a pile had been driven from thirty to forty feet it would suddenly spring back two or three feet after a blow. That was when it had struck the hard gypsum, which had to be cut out with steam.

The early summer of 1902 found more than three thousand men in the company's force on the cut-off. A thousand of them were busy on the permanent trestle alone. Work was progressing rapidly at several places. The great gravel pit at Promontory Point and the quarry at Lakeside were beginning to send out their trainloads of gravel and rock, and the yard at Hogup was pouring out its tons of material along the enbankment at the western shore of the lake. Things were going smoothly and the sky was fairly serene. From both sides of each arm of the lake the work advanced.

Many of the men brought out their families, and to each the company allotted an " outfit " car in which they lived. The men bought their supplies in Ogden, and the company hauled them out free of charge. Long lines of these box-car homes stood on the temporary sidings, and flocks of children played about in the yards. At Lakeside forty or more such cars stood in one string near the quarry. It was not intended by the blasts there to do more than shake up the rock so that the big steam-shovels could handle it. But sometimes, when blasts were unusually heavy, pieces flew uncomfortably near the outfit cars. So it was ordered that at the cry of " Blast! " all the women and children should come out of their wheeled houses and crawl under them for safety.

Good luck attended the work. There were plenty of accidents of the minor sort, limbs broken and hands smashed, but only one that was serious, caused by a collision which exploded a car of dynamite. Several men

fell into the heavy salt water and came near strangling. Of all who fell not one thought to shut his mouth and keep the brine out of his throat. The company maintained a hospital on the work, with surgeons in constant attendance.

Mr. Hood planned to have the roadway on the permanent trestle fifteen feet above the normal high stage of the lake. The margin on the fill was not so great, because if at any time the water should rise threateningly it could be easily and quickly raised. The top of the fill is twenty feet broad. In twenty-four feet of water, the greatest depth it was undertaken to fill, the enbankment, as planned, was therefore a little under forty feet high. As finally made, it is something like fifteen times that. Under normal conditions a fill forty feet high and twenty feet broad at the top will be about a hundred and forty feet broad at the bottom. But in this fill it was from two to four times that.

The brine of the lake is so heavy that it fairly floated away the lighter material. Gravel and dirt seemed almost of no use. The slope of the embankment, instead of being steep and sharp as above water, fell away, often as gradually as a bathing beach on the seashore. Tons and tons of material seemed to disappear altogether. This was one of the things that had not been foreseen. Some allowances had been made for the unusual power of flotation of the salt water, but not enough. There are places where the material of the fill can be traced for three hundred feet or more on each side of the track. It was rock that counted in this work. Great chunks of it, weighing thousands of pounds, were thrown in, only to be swallowed up by the insatiable bottom of the lake. But at last the effect began to be felt, and then the smaller material had a chance.

It was on the fills that all the trouble and struggle took place. There was never a hindrance on the permanent trestle, save when now and then a heavy storm smashed a log boom and sent the scattered timbers and piles cruising about the lake on their own account, to be slowly and painfully collected again by the launches and towed back to new booms, while the men in the boarding houses played cards, read, smoked, and talked, and drew their pay in idleness.

Thus a year went by and the temporary track was completed the whole length of the cut-off. Then the devilment began. It was as if the old lake had not realized what was going on until, just as the task began to reach the hopeful stage where the work showed what was doing, she suddenly awoke and bestirred herself to its undoing. On March 24, 1903, the first engine was started across the cut-off. Up to that time it had been the practice to back the material trains out to position for dumping.

There were two spots that had been specially difficult to handle, one in the east arm, about the old Bear River bed, and the other in the west arm, near the station called Rambo. The fill was not as yet nearly up to grade in either place, although it was well above the water. The trial engine pursued its course leisurely until it struck the old Bear River bed, and then, without warning, the embankment settled out of sight and the engine stood in a foot or two of water, but still on the rails. Thereupon a cable was attached to her, and she was hauled out.

That was the first. The track was raised again and the fill brought back to its old level. A week later it went down under a work train, and gave the men a good start, although no one was hurt. So it kept doing. Always the settling stopped when the top of the fill was a little

under water, and often the track was left wriggling and squirming on the surface. The treacherous crust on the bottom had given way under the weight of the fill. As often as the embankment reached a certain height and its weight thrust too great a strain on the limitless mud on the bottom, the mud gave way, and down the whole structure sank to the point where the strain was relieved.

Here the real work of building the Lucin Cut-Off came in. For a year and nine months that thing kept up, and the day on which there was not a sink somewhere along the job is crossed and starred and bordered with red on the calendars of the engineers in charge. That first sink began a fight the like of which has not been seen in railroad engineering. It became, apparently, the stupendous task of filling up the bottomless pit. Twenty-five hundred men were at it day and night without cessation. Every hour saw at least one great material train thrust out on the crazy track to pour its tons of rock and gravel into the greedy, yawning hole. The daughters of the horseleech had their home at the bottom of Salt Lake, and Mr. Hood had taken on the task of stopping their mouths. It was a fine exhibition of pluck.

"We know what it ought to do," said one of the engineers, "but what we don't know is why it does n't do it."

There was only one course for them, and that was to keep on filling. Gradually they saw their work beginning to tell. The embankment reached a greater height above the water before it sank, and they knew that sometime they would get it up to grade and it would stay.

The permanent trestle was completed, with its roadbed laid on three inches of asphalt roofing over heavy planking put down on twelve-inch stringers, and ballasted with fourteen inches of gravel and rock. The solid waves, that it had been prophesied would twist and

tear and perhaps smash the big piles, rolled harmlessly through them, and instead of damaging, pickled them in brine and covered them with a coating of salt and soda that bids fair to preserve them for all time. Only on the embankment did the wash show any effect, where sometimes it rolled away large rocks.

The fill was now up to grade — at times — along its entire length, and the regular track was laid down. On Thanksgiving Day, 1903, Mr. Harriman came with a party of friends and railroad men to see the formal opening of the great work, but it was not until the 6th of March, in the following year, that the condition of the track seemed to warrant diverting traffic from the old line, and even then it was only freight trains that were sent over the cut-off. Passengers continued to use the old road for several months more.

By this time all the fill except at the two bad places had come to a stable condition. Bear River was approaching good behavior. For four months the track there was operated at a foot or eighteen inches below grade with no sink. Then it was raised to grade, and promptly went down eight feet. But that was the last. It was filled again to grade, and there remains.

But Rambo still made trouble. Beginning with April, 1904, a careful record was made of the settlements of the fill about that station. In a period of two hundred and eighty-seven days there are four hundred and eighty-two entries, with only nineteen days on which no settling was recorded. August was the worst month. There are eighty-four entries for that month, seven of them on one day, the 23d. But this does not mean that the same section of track sank eighty-four times that month or seven times that day. They were seven different sections, ranging from two hundred to eleven hundred feet

in length and covering a total of thirty-six hundred feet out of six thousand feet affected. The greatest settling was about four and a half feet and the average less than two. Of such sinks there were thirty in August, one glorious day being free.

But even with these sinks the freight traffic continued with less interruption than it had suffered over the old line. And as fast as the track went down it was raised again. The total raise, both at Rambo and at Bear River, was something over seven hundred feet. Now the engineers saw what was becoming of the material they were heaving into the water at this rate — seventy thousand cars of rock alone went over the dump at Rambo. Off at each side of the track, from a hundred to three hundred feet away, little islands or bars rose out of the lake. Piles driven in the temporary trestle came to the surface and once or twice were forced clear out, a hundred feet or more from the track. A lady crossing the cut-off with one of the engineers saw this phenomenon and exclaimed:

"How fortunate it was that you found those little islands!"

"Found them!" cried the engineer. "It took us two years to make them!"

On the 18th of September, 1904, passenger trains were first sent over the cut-off, and from then until the middle of January, 1905, only thirty-four minutes, all told, were lost by them on the new track, far less than the average delay on the old road. December 23, 1904, was the last black day in the record. That day two hundred feet of fill near Rambo went down a little more than a foot. The Lucin Cut-off was complete, and Mr. Hood, the engineer, was justified in his faith. So, too, was Mr. Harriman, the financier; for in January, 1905, the operating expenses of the new road were sixty-one thousand dollars less than

the operating expenses of the old road in January, 1904, although the traffic was greater.

With six hundred thousand tons of through freight annually, and that amount increasing, the old road had reached its limit. It took three locomotives to handle nine hundred and fifty tons, and often required from thirty to thirty-six hours. Over the cut-off a single engine has hauled two thousand three hundred and sixty tons in less than nine hours. Passenger trains that used to go in two or three sections, each with two locomotives, now run from fourteen to seventeen coaches with one engine.

When you sit in the observation car and gaze at these miles of fill and trestle, you will not see a strikingly spectacular piece of engineering accomplishment, but you will see the monument of one of the greatest exhibitions of pluck and endurance ever made. And when you talk with one of the men who made it, he will tell you of this or that sink, and joke at the recollection of those almost despairing days.

OVER THE FLORIDA KEYS BY RAIL[1]

By RALPH D. PAINE

A SPECK of reef set far out in a tropical sea, much nearer to the coast of Cuba than to any port of its own country, Key West has long been the most remote and incongruous city claimed by an American state. In days gone by its spongers, wreckers, and Spanish-speaking cigar makers no more dreamed of being linked with the mainland by rail than do the people of Honolulu. Until twelve years ago their nearest home port was Tampa, two hundred and fifty miles up the Gulf of Mexico. Then the Flagler railroad, which had been advancing down the strip of wilderness along the Atlantic seaboard, brought Key West within reach of Miami, one hundred and fifty-seven miles away, by steamers which skirted the far-flung chain of the Florida keys.

This chain of islets swings off from the Everglades of the mainland to stretch down into the Atlantic and the Gulf as far as Key West. Worthless, chaotic fragments of coral reef, limestone, and mangrove swamp, most of them are submerged by high tides and have been aptly called the sweepings and débris which the Creator hurled out to sea after He had finished shaping the Florida peninsula. No part of the western frontier or desert is so primitive and unpeopled as was this swarm of seagirt islets until a man with a dream of creative achievement, and millions of money to make it come true, resolved to

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build a railroad to Key West. It was to be a railroad which, in a distance of one hundred and thirty miles from mainland to terminus, should bridge no less than thirty miles of open sea, and cross at least thirty miles more of submerged keys and lagoons.

A railroad to be pushed, with stupendous difficulties and at an expense of fifteen million dollars, through the Atlantic to a remote reef — what is the reason for so monumental an undertaking?

The answer lies in Henry M. Flagler's belief that the island of Cuba will some day strike its destined gait of prosperity and growth. For Cuba is the true objective of the railroad to Key West. When the work is finished, huge ferries will carry solid trains to and from Havana; and a through-rail route from New York to Cuba will be completed.

Henry M. Flagler's purpose to stake his fortune on Cuba was the direct result of his visit to the island in company with Sir William Van Horne. Here he learned the scope of the plans for the railroad development of Cuba which seethed in the mind of the great Canadian builder. The man who had constructed more than five thousand miles of wilderness road with fifty thousand men in less than five years, who had shoved the Canadian Pacific through to the coast, was sanguine of doing great things in Cuba.

Mr. Flagler grasped the fact that his Key West road would be an important transportation link in the far-sighted plans of Sir William Van Horne. He found that the Ann Arbor Railroad was conveying trains of twenty-six freight cars on ferries over one hundred and twelve miles of water on the Great Lakes. It was therefore feasible to carry solid trains between the United States and Cuba. And every inland sugar planter, who had to

ship his crop by rail to tidewater before finding steamer transportation, could be offered a competitive rate, for handling and freightage, over the all-rail route via Key West.

A railroad to Key West would serve other purposes as well. As the quickest route for mail and passengers between the United States and the Panama Canal, as a long stride nearer the commerce of South America, as a military and naval base of immense strategic importance for coming generations, a terminus "farthest south" appealed to Mr. Flagler's imagination. Moreover, the idea of a sea-going railroad was, in the last analysis regardless of the immediate impetus, the logical climax of his prodigal investments along the east coast from Jacksonville to Miami. Here he had already spent thirty million dollars in twenty years extending his chain of magnificent winter resorts farther and farther south, and binding them together with his railroad. To make of it a through system he had inevitably to push it on toward the Gulf.

The story of this railroad building is quite like a tale from the "Arabian Nights." The viceroy chosen for the work was Joseph R. Parrott, a broad-shouldered, square-jawed man in his forties, who was already carrying enough responsibility to bury several ordinary men. He was a Yale athlete of such ability that he had rowed on five university crews and had been substitute on a sixth. Coming to Florida fresh from the Yale Law School in 1885 to take a berth with the legal department of one of the first railroads in the state, he was induced to join Mr. Flagler's interests twenty years ago. He became the one-man power in direct management of property interests which expanded year by year until they had reached vast proportions.

He had to create the East Coast Railroad system, and to equip himself to handle the greatest hotel interests in the world, on top of which tasks he was requested to put a railroad into Key West and was made wholly responsible for the undertaking. Fourteen thousand people have been on his pay-rolls at one time in Florida. And the enterprises controlled by him have involved from thirty to forty millions of capital.

The first plan for extending the railroad south of Miami attempted to find a way across the Everglades to Cape Sable, the southernmost tip of the Florida Peninsula, eighty miles from dry land. Engineering parties spent months at a time in this, the most hostile and inaccessible wilderness left in the United States. They suffered such hardships and torments as have been endured elsewhere only in the heart of Africa. One outfit had to be rescued by a relief expedition and was found on the edge of starvation. The survey was carried through to Cape Sable, the land was found impracticable for railroad building, and the field of action was therefore shifted to the route across the keys. Locating this erratic line was an Alice-in-Wonderland task of itself. The surveying party had to do most of its work afloat, and some of its men were lost among the hundreds of keys for days at a time. They wished to utilize as many of the keys as possible, and finally selected forty-one across which to run the road. There were gaps between them so wide, however, that towers had to be built for sighting the instruments. In other words, these distances which must be bridged were so great that the curvature of the earth hid the rodman on the key from the man with the transit.

The next step was to find the right construction engineer, for upon this official's ability the enterprise must hang in the final issue. Down at Tampico, a fragile-looking, sun-

burned man of middle age was putting three and a half million dollars belonging to the Mexican Government into a pier half a mile long. He was a taciturn, almost diffident, person, this quiet little engineer, J. C. Meredith by name. But he knew all about reënforced concrete; he had built bridges all over the face of the map, and his hard-working brother engineers considered him a man of much courage and resourcefulness. After he had finished with his tremendous Tampico pier, he was summoned to confer with the viceroy, J. R. Parrott. The latter expected the engineer to demand a month to look over the ground and another month or so to make up his mind, but to his questions Mr. Meredith replied:

"I 'm ready to begin work this afternoon, but I 'd like a few days to go home to Kansas City and pack some things and see my family, as I 'll have to be on this job for several years."

As soon as the engineer reported for duty, he began to study the surveys of this extraordinary railroad proposition. It had many novel aspects. He had to determine beyond guesswork the effects of hurricane-winds and tides, to provide the greatest possible wave resistance along every foot of the way, to study and tabulate the data recorded of every West Indian hurricane that has swept the keys since records have been kept, and to lift his work wholly out of the field of experiment. Having satisfied himself that his work would stand the test, he made the plans for his mighty viaducts, and the foremost engineering authorities of this country looked them over and said they were flawless.

Then Mr. Meredith began to build his railroad by the upside-down process of digging more than thirty miles of navigable canals through the Everglades, which barred his progress from the mainland to the keys. These canals

were dug by powerful dredges, which were built in holes in the ground. Then water was let in to float them and they began to eat their way toward the sea, throwing up the mud between them to make a railway embankment and leaving two canals in their wake. The grading of the first seventeen miles was accomplished in this fashion. The bed rock was so near the surface that the dredges sometimes stranded and could no longer dig their own way. But presently Engineer Meredith evolved a system of locks by which the stranded dredges were floated over the barriers of rock.

Meanwhile, Mr. Parrott was assembling men and material for the invasion of the keys. At one time he had under charter every available freight steamer flying the American flag on the Atlantic coast, and, still being short of vessels, he had to import cement from Germany to get bottoms to carry it. The crushed rock ordered for the viaduct construction filled eighty tramp steamers, two hundred thousand tons of coal freighted another imposing fleet, and the cargoes of steel, lumber, and supplies bannered the sapphire sea with the smoke streamers of deep-laden tramps. Camps and a transportation system had to be arranged to care for five thousand men far from the mainland, along a hundred-mile fringe of keys with no more than two deep-water harbors in this distance.

Efficient labor was in demand the country over, and good men did not want to fight mosquitoes in the isolation of the Florida Keys. Thousands of good-for-nothings, the dregs of sodden and broken humanity, had to be shipped from Northern cities out of sheer necessity. Negro labor could not be obtained in such prosperous times, and the law forbade the importation of blacks from Nassau and Jamaica, or Spaniards from Cuba and their own country. The sources of labor supply depended on

for digging the Panama Canal were closed to this American enterprise.

Hordes of " hobos," as they were classed, were sent out of the camps as worthless, or because they refused to work at all, scorning even to earn the twelve dollars advanced them for transportation. Although the average number of men employed was about four thousand, the pay-rolls show that twenty thousand men were carried to the keys in three years.

In addition to heat and mosquitoes and loneliness, the company's edict against whisky in the camps proved a discouragement to laborers. And the company was able to enforce this mandate because the rum-shops of Key West and Miami could not be reached on foot. To supply the crying demand a fleet of outlaw " booze boats " skulked among the key channels as old-time buccaneers did in these same waters. The engineers waged war against these pirates because they were beyond the law, and the " booze runners " took chances of being peppered with rifle fire or of diving overboard just ahead of a stick of dynamite.

The process of weeding out laborers was costly and disheartening. When the working force had been hammered into something like efficient shape, a hurricane swooped down on the keys in October of 1906 and not only tested to the utmost the work of the engineers, but made havoc in the ranks of the laborers. The construction had been well advanced, however, and embankment, trestle, and viaduct stood the trial without serious damage. The soundness of Mr. Meredith's plans could have had no finer vindication, but the hurricane cost the lives of one hundred and thirty men, blew the camps to tatters, and swept vessel after vessel of the costly floating equipment out to sea.

Many of the laborers were living in huge barges, or " quarter boats," with two-story superstructures. These craft were towed from key to key as the work advanced. One of them, " Number Four," was torn from its moorings at Long Key before the one hundred and forty-five men aboard could try to get ashore. Shortly before daylight it drove out across the Hawk Channel in a smother of sea and a roaring wind, and was smashed on the back of the Florida Reef. The great barge was pounded to pieces in a twinkling.

But there were men in her who showed heroic stuff even in this terrible situation. Bert A. Parlin, one of the resident engineers, and the ranking man aboard, might have saved himself, but he went below to try to put heart into his men, and was killed by a flying beam when the superstructure collapsed. The men who had the grit and courage to use their wits crowded out on the balcony to windward to escape this falling wreckage and swore that they would pull through. Those who had the *will* to live were saved under almost incredible circumstances, while the cowards who had crowded into the hold perished to a man.

As the " quarter boat " floundered toward the reef, with the seas breaking clean over her, with death for all on board apparently certain, a barge whirled past her in a fog of spray. Two mechanics, Kelly and Kennedy, stood side by side on the deck of the " quarter boat."

" That barge looks good to me," said Kelly.

" I 'll go you," replied Kennedy.

Kelly jumped for the barge as it sped past, and Kennedy was at his heels. A gray sea rose and swallowed them, and their comrades counted them as lost. Almost a week later, the barge was picked up with Kelly and Kennedy aboard, crazed and almost dead for want of food

and water. They recovered and returned to the keys. As many as eighty-seven of these " quarter boat " men were picked up out of the sea alive. With remarkable strength and with courage truly indomitable, they had ridden out the hurricane clinging to bits of wreckage, to tables, and to trunks. The Italian steamer Jenny passed them late in the afternoon of the day of the wreck, found forty-four of them, and took them into Key West. Her boats risked the dangerous seas all night long, and it is tragic to record that they heard the voices of others in the darkness, but were unable to locate the calls for help. The British steamer Alton picked up twenty-six more and landed them at Savannah.

For days and weeks news of other castaways came from distant ports, Mobile, Galveston, New York, London, Liverpool, and even from Buenos Ayres, whither they had been taken by ships. Without boats or life-preservers, knowing nothing of the sea, undisciplined for such a crisis, these hardy toilers battled for life with a success which makes their story remarkable in the annals of shipwreck.

Of forty-nine men who went out to sea in two house-boats, only one, John Russell, was saved. He floated on a couple of planks for three days, was blinded by salt water, and heard ships pass him in the night, before he was seen and picked up and taken into New York.

There was something fine about the finish of one Mullin, left in charge of a cement-mixing plant on board a barge. He was alone when she went out to sea, but there was an electric-light plant on board his craft, and as long as those ashore could see her in the gray dawn, Mullin's lights were blazing like a Coney Island steamboat. He was stoking his boiler and sticking to his job until the moment when the sea swallowed him up.

Another lone hero on one of these cement barges found himself blown out into the wild Atlantic. Instead of giving up the game as hopeless, he set to work with his wrench to loosen the bolts which held the cypress box of a water-tank to the deck. Stowing himself in the tank, he stayed there until the barge sank under him; the big box floated off and he drifted in it right side up for several days until he fetched the coast of Nassau.

As swiftly as possible, after the hurricane, the working force was reorganized, and from the clusters of tents and house-boats the working gangs swarmed by night and by day to carry the white trail of the grade southward. Across most of the northern keys they found a bed of coral and limestone; this was blasted and heaped in embankments by hand labor as in ordinary railroad construction. Many of the open-water stretches were crossed by means of ramparts thrown up by suction dredges, which trailed their long lines of pipe across the channels like huge serpents. These crossings were riprapped with rock to buttress them against the wash of the sea. Behind the graders came the track-laying gangs, coupling up one key after another to the mainland, while the camps ahead of them were shifted farther south to invade the islets that swam in wonderful opalescent lagoons. From the top of a derrick frame the finished grade stretched across the green keys like a straight white ribbon.

The line came at length to a bay four miles in width between Lower and Upper Metacumbe Keys. The land is so low that the farther shore almost dipped below the horizon. Across this body of water the railroad pushed its way on trestlework and rock embankment, all of which will be filled in solid before the work is finished. Then the builders brought up at Long Key, where the first great viaduct was constructed.

For two miles across the green sea this structure towers as a wall of masonry carried on noble arches — one hundred and eighty of them, built of concrete reënforced with steel. It has the aspect of a Roman aqueduct built of solid stone, and its colossal strength and dignity of outline are framed in a setting altogether lovely. Seen from the shore of Long Key, its arches march across the water, away, away, until they seem to run sheer into the horizon with nothing to mar their splendid isolation. Save for the low keys at either hand, there is no land in sight anywhere, nothing but ocean shifting from green to blue as it rolls to the Gulf Stream on the one hand and melts into the western sky on the other. A passenger on a train crossing the Long Key viaduct may be lucky enough to see a school of flying fish skitter past and a porpoise or two hurtling in chase of them. The cost of this one link between the keys was a million and a half dollars for two miles of construction, but unless a ferry is operated so that the traveler may see it from a distance, he will miss any adequate view of this noble and impressive structure.

Only one more stretch of open water comparable with this remains to be bridged. It extends from Knight's Key to Bahia Honda. Even after seeing the Long Key viaduct, the observer can not view this great expanse of sea below Knight's Key without a sense of wonder and incredulity at the thought that it is to be bridged. Before him shimmer seven miles of ocean to the farther key, seven miles without a square foot on which a man may walk dry-shod. In fact, Bahia Honda Key is so far distant that it dips below the horizon and is invisible from the water's edge. So far as can be seen, it is a matter of launching a railroad straight at the blank horizon of the Atlantic.

Of this seven miles of sea, three miles will be bridged

by two concrete viaducts of equal length, leaving four miles of solid rock embankment to be raised. Omitting this unfinished work, the completed road to Knight's Key has wrought itself over thirteen miles of open water and nineteen miles of submerged swamp in ninety-two miles of track. It is a railroad built of rock and concrete for so much of its length that it is virtually a sea-wall. The Government at Washington became uneasy at the notion of a solid wall stretching from the mainland to Key West, fearing that it might shut off the tidal flow and so disturb the aquatic equilibrium of the Bay of Florida. Thereupon the railroad builders were respectfully informed that they must leave a certain number of bridges by way of openings in their embankments, in order that the immemorial habits of the tide should not be hampered.

While the prevailing shallowness of the water has made it possible to throw up mile after mile of embankment, it has made the problem of transportation immensely difficult. It was found impossible to approach, even in light-draft launches, many of the keys, on which hundreds of men must be camped and fed. A flotilla of stern-wheel steamboats from the Indian River and the Mississippi, reputed to be able to navigate in a heavy dew, was imported to operate on these lagoons, but they ran hard aground miles from the places they sought to reach. "Not quite enough water for swimming and too d—— much for farming," was the way one disgusted skipper voiced his opinion of the Florida keys.

In the forty miles from Bahia Honda south to Key West the island formation differs as radically from the keys to the northward as if they belonged to another geological period. The coral rock disappears and what land there is is of solid limestone. The keys are so low that many of them are mere swamps densely covered with

mangrove. Throwing up embankments across them has been largely a matter of dredging. And for this particular kind of dredging Mr. Meredith designed a new species of amphibious monster. All known methods of railroad building had to be discarded. To feed any of the usual types of dredge with coal and fresh water was impossible because supplies could not be transported over the shoal lagoons and landed within reach. Therefore Mr. Meredith evolved a startling innovation by using a gasoline engine as his dredging power. Six of these gasoline dredges were built on barges. Where there was enough water to float them, they waddled across the key, indefatigably heaping up embankments. When they came to a dry bit of going they were yanked ashore, mounted on wheels, slid on to a steel track, and so progressed as effectively as ever.

As the construction camps floated in among these southern keys, they invaded the haunts of scattered and solitary dwellers in their fastnesses, here a pure-blooded Conch, or native of the keys, whose forefathers had drifted over from the Bahamas, dropping their "h's" en route; there a renegade from some civilization which had cast him out. Or it might be such a picturesque figure as the withered Montenegrin, Nicholas Makovitch, who has set spring guns around his cabin for some thirty years and who refuses to discuss his past. Such denizens as these sculled their skiffs across the lagoons to wonder at this infernal invasion of their private rights by the railroad grade that rose as if by magic in the flooded swamps.

Tiny clearings were brought to light in which the aguardiente smugglers from Cuba have made their rendezvous for generations. Every Cuban revolution for a century past has sent swift vessels to flit among these keys and pick up hidden stores of arms and swarthy

leaders waiting to return from exile. The old-time wreckers of the Florida Reef have sailed through these labyrinths to land and to divide their spoil after arranging a wreck beforehand, for many a shipmaster has lost his vessel in these waters for a price.

While these serried keys were dotted with camps and their waters swarmed with the fleet of the builders, Key West itself awakened to such feverish activity as it had not known since the Spanish War. Then the crooked old streets were filled with war correspondents, real and alleged, and with groups of men and officers from the gray cruisers and battle-ships of Sampson's fleet. Now the host that flocked in to arouse the town from its tropical calm was made up of dredging crews and laborers commanded by tanned young engineers. They mobilized their digging machines along the water-front, streaked the island with a railroad grade from end to end, and boosted the prices of real estate by leaps and bounds.

When J. R. Parrott reported to H. M. Flagler that there was no room for deep-water terminals along the harbor front, he was told to go ahead and make enough dry land to serve his purpose. This in itself was a princely undertaking, for it meant filling nearly two hundred acres of salt water, a good-sized town site, with material dredged from the bottom. Suction dredges pushed their tentacles far out to find mud enough to feed their hungry maws, and an army of men built a sea-wall of rock to contain this filling. Already almost a hundred acres have been made terra firma, and the outline map of Key West has been considerably altered. The Federal Government appears to have been afraid that the energy of these railroad makers was likely to play hob with the geography of Florida, for, as the work progressed, again there were

signs of uneasiness at Washington. The Navy Department protested that it might some day wish to make a torpedo station of one of the near-by keys, and would need some mud for filling it. At the rate they were working, these railroad dredges would soon scour Key West harbor clean.

Mr. Parrott thereupon agreed to replace all the mud exactly where he had found it, in the event of the Government's needing it. This very courteous offer was accepted, and the incident closed with no mud-slinging by either party.

The tourist journeying south to Knight's Key will find maps and time-tables of little help in getting his bearings. When the road runs through to Key West, however, he will be able to chart his course by the string of lighthouses along the Florida Reef, ten miles out to sea. These spider-legged skeleton towers of steel rise from the open sea, one after the other, visible from the railroad by day, flashing their several beacons by night. Sombrero Reef, Alligator Reef, and American Shoal Lights will serve the traveler in place of mile-posts and stations, which is just as it should be on this seagoing railroad.

Besides, as he is carried over salt water through long hours of sunshine, with the wind sweeping sweet and cool through the open window, he may watch the stately procession of south-bound ocean steamers which pass close along the Florida Reef in the great tide of traffic to the West Indies, to Central American and South American ports. Nor is it at all fanciful to suppose that if he is wise enough to carry a fishing-line and bait, he may find lively sport from the car platform should the train happen to halt on the Long Key or on the Bahia Honda viaduct.

THE GREAT COMSTOCK MINE [1]

A CITY UNDERGROUND

By CHARLES HOWARD SHINN

WE are to study at its best the great subterranean city, the chain of works for whose maintenance and extension, mills, machinery, and towns on the surface were created. We are to go down the main shaft, stop at a "station," explore a drift, see the miners at work, and hear stories of peril and adventure.

The visitor retires to a dressing-room, takes off his or her ordinary clothing, puts on one of the suits kept there for the purpose,— flannel pantaloons, woollen shirt, heavy shoes, and felt hat,— is placed in charge of a foreman, and they enter the cage. The foreman waves his hand; in an instant we are dropping noiselessly into the darkness, lit only by the flickering rays of a lantern which shows timbers seemingly leaping upward.

Pretty soon a station appears, but we pass without pausing. There seems to be a large irregular room opening back from the side of the shaft. Men are busy there, moving about in the well-lighted space, and there is machinery at work. If we went slower we should see a drift extending from the station and dividing into many other passages, and miners and foreman would be noticed passing to and fro engaged in various occupa-

[1] Reprinted from Shinn's "The Story of the Mine." Copyright, 1896, by D. Appleton & Company.

tions. Every hundred feet a station flashes past, and the immensity of the work begins to grow upon the traveler.

Sometimes the man in charge of a station hails us as we pass, and the foreman makes a reply that is Choctaw to the uninitiated, for we are dropping rapidly away from the sound. As we reach a depth of a thousand feet or so the cable sometimes begins to "spring" with a peculiarly disagreeable bobbing motion, which gives a novice a new sensation, as if hung in an abyss by a rubber strap. In the midst of this we come to a full stop at the fifteen-hundred-foot station and step off on the floor.

A station is the office for the work done on that mining level, as well as the point where men stop and where freight is shipped or received. It is walled, roofed, and floored with huge timbers and planks, and is a large, well-lighted place crowded with mining supplies, barrels of ice water, candles, fuse, powder, tools, etc. If it were not for a car track which crosses the middle of the floor, coming from the level beyond and connecting by switches with all the hoisting compartments of the shaft, the place would sometimes seem a combination of office and country store. The car track that extends through the main drift of the mine connects by turntables with the side drifts and cross-cuts. Laden cars arrive regularly from the "stopes," or places where ore is being taken out, and are sent to the surface by the station tender. Empty cars as they arrive are returned to some place where they are needed by the car men, and so the work goes on steadily, excepting when shifts are changed.

The drifts, or "galleries," as some call them, are from four to six feet wide and seven to eight feet high. The miners prefer to cut them outside of the vein as much

as possible, as there is less danger of caves. The floor of a drift is horizontal, or slightly raised, to facilitate the delivery of ore. The main north and south drift is the Broadway of the level, and sometimes even contains a double car track. The cross-cuts start from the main drift at right angles with the vein, so as to cut into the ore body, if any is found. Like the levels, they are about a hundred feet apart. They are extended entirely across the lode to the other wall, and are connected with each other by cross-drifts.

Every new cross-cut attracts the attention of all who are interested in the mine. If one cross-cut is in pay ore there is much greater excitement when the next one, a hundred feet farther on, is to be opened. In this way, with drifts, cross-cuts, and cross-drifts, the skeleton of the underground plan begins to be apparent. Imagine a general plan something like this on each level, and we only have to describe the winzes to complete the framework of the passageways.

A winze is a small shaft sunk wherever it is needed, from one level to another, for ventilation, to explore new ground, or often, when sloping, to serve as a chute for ore and timbers. An " upraise " is the beginning of a winze started on a level and carried upward toward the next higher level. If it is finished its name is changed to winze. The only connection between one level and another besides the main shaft is by means of these winzes. Vertical winzes are in reality shafts; sloping winzes are inclines; drifts, cross-cuts, and cross-drifts are really tunnels.

The main shaft which connects all these underground workings is not always vertical, neither does it always remain the same for its entire length; it may be an " incline," as the Crown Point shaft, which is vertical to the

eleven-hundred-foot level and then follows the lode, which dips thirty-five degrees at that point. The car used for hoisting through an incline is a "giraffe," absurdly called so "because the hind wheels are very large and the front ones low, so as to keep the car level." One would suppose that the name kangaroo would be more appropriate. It carries eight tons of ore at a trip. Sometimes another or "back-action" car is fastened behind. A ride on a giraffe is very exciting. The track is well lighted and the cars climb it with the speed of a lightning express. The giraffes, like the elevator cages, have safety grips. At the bottom of the shaft or incline is the "sump," a pit or well sunk there to collect the water from the mine. Here are the suction ends of the pumps.

To have a main shaft presupposes that there are some air shafts for ventilation; but there are few on the Comstock, ventilation being secured as far as possible by connection with the main shafts of other mines. The miners agree that the direction of a draught in a mine remains permanent for years, but if a fire in a mine changes the draught, it never changes back. A "down-cast" has thus been changed in an hour to an "up-cast." The general tendency of air currents in the Comstock is in the same direction as the slope of the ore chimneys — that is, southward. Each new connection makes changes in the air currents in all the mines.

There is machinery in the mines, and often a great deal of it. Steam makes too much heat, but compressed air, hydraulic power, and electricity are now used with entire success. Small engines run the "blowers" to force fresh air through pipes to every part of the mine, but particularly to the heads of the new cuts, drifts, and upraises; others hoist and lower rock and other materials in the various winzes, and still others drive the

drills. All this makes a network of pipes, mostly for compressed air, extending throughout the mine.

The admirable system which prevails is nowhere more manifest than in the way men are handled. They form in line in the hoisting works and march into the cages. They leave the mines in the same way. Three shifts of eight hours each make the day of twenty-four hours. "Morning shift" is from seven in the morning to three in the afternoon, "afternoon shift" from three to eleven in the afternoon, and "night shift" till seven again. Each level of the mine has therefore its three shift bosses.

The clerk who acts as time-keeper has an office in the hoisting works and registers every man's ingoing and outcoming with the regularity of a machine. The shift bosses report men missing or sick, also accidents, or anything else of importance. They tally loads of ore and waste rock, filling up a printed blank. The superintendent thus knows how much work each shift has accomplished. Each level has a foreman. The mine has also a general underground foreman, and an assistant to take his place at night.

As regards the workmen, there is complete classification. The timber men attend to the supports of the various workings; the miners, drill men, and drifters hew and cut passages and extract the ore; the pump men and engineers see to their respective duties. Watchmen make regular rounds, messengers carry orders, take the men water or tools, and gather up the dulled picks and crowbars to send them to the forges.

Lamps, candles, and electric lights gleam along the rocky aisles of the mines, except in long unused portions. Since one mine is connected with another on the various levels, the boundary lines being accurately marked on the walls of the main drifts, the longer streets of the under-

ground city extend for three and four miles, and in active times men are met at almost every corner and turn, singly or in groups. It is a busy, populous city, and its inhabitants are a superb race of men, white-skinned twilight-dwellers, naked except for shoes, overalls, and small felt caps.

They go about quietly with hardly a word to one another. It is a land of silence as well as of candlelight. One begins to understand why miners have always made such unconquerable soldiers at times of national need; these men are soldiers already in their power to yield prompt obedience and in their capacity to move together in solid phalanxes.

On the Comstock the arch enemy is heat. "View their work!" says Mr. Lord in his history of the lode. "They enter narrow galleries where the air is scarce respirable. By the dim light of their lanterns a dingy rock surface braced by rotting props is visible. The stenches of decaying vegetable matter, hot, foul water, and human excretions intensify the effects of the heat."

The men can not wear woollen garments, they perspire so freely. In the most heated parts of the mine they work ten or fifteen minutes, then run to thrust their heads under cooler water from the pipes, and to breathe deeply the fresh air forced out of the blowing tubes. They soon become so exhausted that the shift boss orders them back to lighter work in less torrid drifts. Miles of passageways have been cut in air so unendurable that candles burned blue and went out, and men falling down were dragged back by their comrades.

About 1868 it began to be noticed that the points of greatest heat in the lode moved considerably from year to year, as if the hot-water streams sometimes filled one part of the lode and sometimes another. Crown Point,

on the fourteen-hundred-foot level, struck a stream so hot that eggs were readily cooked in it, but a year later the heat at this place was much lessened. Bullion on the seventeen-hundred-foot level registered one hundred and forty degrees Fahrenheit.

About this time an enormous vein of hot water was tapped at various points along the lode. It has been estimated that the water pumped out of the Comstock at this period and the air in circulation through the mines were together removing annually an amount of caloric that was the full equivalent of that produced by fifty-six thousand tons of the best anthracite coal, burned in the most economical manner. Notwithstanding this constant extraction of heat from the lode, the temperature continued to increase, though with many fluctuations, as greater depths were attained in the various mines.

Besides this intense heat of the lower levels, the hot water met with in running drifts and cross-cuts is sometimes so poisonous with the minerals it contains in solution that when a vein is tapped it blinds every miner in that part of the workings. Their faces swell and their eyes remain closed until they have been some time in the open air and under medical treatment.

Then, too, the old shafts in the upper levels, long ago abandoned and marked " dangerous " on the mine maps, have been left to darkness and decay. Acres of underground passages and ore chambers here are ghastly, crumbling ruins, trembling under the step of every explorer. Timbers are twisted and crushed to half their original length or pressed together by the weight of the mountains overhead until they seem like flattened, broken, entangled straws in the " lake " of a cider press. Occasionally some one creeps along the remaining crevices into the shapeless and fast-closing chambers of ancient bonan-

zas. The foul and musty odors of a charnel house fill the hot, dripping desolate darkness; moist and slimy fungi of gigantic size and strange shapes grow out of the walls and timbers; fire damp fills many of the drifts, and dangerous explosions occur; phosphorescent lights glow at times in these tangled tropical forests overthrown and crushed together, and in winter nights abandoned shafts are sometimes illuminated with dazzling blue flames that might serve for the witch scene of an opera.

The ordinary accidents which are everywhere inseparable from mining life occur on the Comstock in every possible form, only on a larger scale than usual. The character of the vein matter would be termed "extra hazardous" by every mining man. Three hundred fatal accidents and six hundred "severe injuries" were reported in the files of the Virginia City newspapers between 1863 and 1880. It is safe to estimate that from the time the mines were opened in 1859 to the summer of 1893 — thirty-four years — there have been six hundred fatal and twelve hundred severe accidents on the Comstock. The years for which the statistics are most complete show inexplicable variation. Accidents seem to go by groups and seasons, and there are many superstitions respecting the subject among miners themselves.

Although not the greatest source of mining disaster, according to statistics, a fire is by far the most dreaded of all accidents. In some mines there is but a single shaft up which to escape, and smoke and explosive gases add to the dangers. There may be eight or nine hundred men compelled to take their turns to ascend the shaft in the cages; the gas explosions put out most of the lights, and men rushing to escape fall headlong into winzes and chutes. Other accidents only endanger a few men nearest the scene, but when the timbers take fire every person in the

mine is in imminent danger. The slightest smell of anything burning is instantly noticed and examined into. A man could cause an excitement throughout half a dozen levels of a mine by lighting a newspaper in a candle, for the smoke would soon penetrate the drifts, and anxious miners would begin to tumble out of every nook and cranny.

The amount of lumber packed into a mine is so great, and the draught in case of fire is so violent, that hurricanes of flames and smoke leap through the narrow channels of rock and beat in resistless waves to the remotest opening. It can hardly be possible to overestimate the inflammability of a well-timbered Comstock mine. Where bonanzas once existed are oval chambers, one or two thousand feet high, packed full of cribs of timbers, with hundreds of floors of two- and three-inch planks on which the miners stood to work away at the roof as they rose on frame after frame from the bottom to the top of the bonanza. There are stairs, timber-lined chutes, winzes, drifts, and cross-cuts, and everywhere, besides the heavy timbers, there are miles of " lagging " behind the frames. Things could not be better arranged for a conflagration.

Some glimpses of the famous fire in Yellow Jacket will serve to illustrate the subject. Here the fire began about seven o'clock one April morning in 1869, on the eight-hundred-foot level, two hundred feet from the main shaft. The morning shift was in the mine when the alarm was given, and Gold Hill and Virginia City were aroused. At the shafts of Kentuck and Crown Point, the adjacent mines, as well as in the Yellow Jacket shaft, blinding volumes of smoke prevented descent. As when a ship is in the breakers grinding to pieces against sharp rocks, those on board are sometimes as completely beyond mortal help as if they were upon another planet, so in this

case the firemen and miners found it impossible to descend not only on account of the black, thick smoke, but because of the highly mineralized and deadly gases which made men faint and dizzy yards from the mouths of the shafts.

A safety lantern was put on a cage and sent down with a message of cheer written in large letters on a piece of pasteboard: "We shall get you out soon. It is death to attempt to come up from where you are. Write a word to us." The cage descended slowly, stopping long at level after level to the lowest point at which any of the men were; it came back without any reply. A draught suddenly drew the smoke out of the Kentuck shaft, and men were able to descend in the cages; they found the bodies of two miners; the gathering of Death's harvest had begun. Crown Point could not be entered, but the smoke and gas drew away from Yellow Jacket after an hour or two, and men began to bring up the dead in that shaft, carrying them through a circle of rope extended about the hoisting works and laying them on the ground.

Firemen took hose, and carried it down the shaft to the eight-hundred-foot level; miners and timber men went with them, putting out flames, propping up falling walls and sides of drifts half filled in places with débris from the roofs. Such a battle in the recesses of a mine equals, and indeed surpasses, in elements of danger and heroism, the fiercest fire battle that men ever waged on the surface of the earth. They played streams of water all day upon red-hot rock and into boiling lakes, and the water ran at scalding heat from the giant pumps. Sudden caves drove poisonous gases upon them; they were paralyzed by fumes of sulphur, antimony, and other minerals, and were sent up the still smoking shaft, whose heavy timbers fortunately had not been destroyed.

After thirty hours of continuous labor the firemen and miners recovered twenty-three bodies. The fire broke out again and again, with new jets of deadly gas; it became evident that no life remained in the ruins, and at last, after several days and nights of unavailing struggle in the three mines, the mouths of the shafts were hermetically sealed and steam was forced into them with all the force of the giant engines. Two days later the shafts were opened and more bodies found, but the fire broke out, and the mines were again sealed. This alternation continued several times, for the whole mining community was determined to recover every body; but the firemen were brought up insensible, even seventy-five days after the first outbreak of the fire. The miners at last walled up the smouldering fire on the eight-hundred-foot levels of Kentuck and Crown Point, where it continued to burn for a year or more. It is a well-authenticated fact that three years afterward there was still red-hot rock in some of these drifts.

The scenes that occurred in the mine when the fire broke out were graphically told in the "Territorial Enterprise" and other newspapers, whose reporters interviewed every man who escaped in the first cage load before smoke and gas had filled the shaft. The story reads like a leaf from the destruction of Pompeii — darkness, smoke, ashes, rains of fire, fatal vapors asphyxiating the panic-stricken people of the submontanic city. The Crown Point miners crowded in the cage, where they hung to every bar in such wild confusion that the station keeper thought many of them would be torn to pieces, and so held the cage until it had only time to escape, remaining behind himself and losing his life. One miner, hastening toward the shaft in the total darkness, all lights having been put out by gas explosions, dropped on his knees and

began to crawl forward till he was at the edge of the shaft. Several other miners ran up from behind, and he heard them fall headlong into the deeps.

Outside, the scenes that occurred as bodies were brought out of the volcano mouth, and, most of all, when the order to seal the shafts were given, were such as abide in one's memory for a lifetime.

The spirit in which the miners meet peril and death is almost uniformly the cool, careless fatalism of many a war veteran. Some of their grim jests still ring like the sayings of old Norse sea-kings. A premature blast in one of the mines once drove a foot-long splinter through the hand of a timber man, through the lagging he was working on, and into the soft rock. "We shan't need a spragg at this end, Bill!" was his cool remark. A "spragg," be it understood, is a square stick of wood six or eight inches long. One end is put against the posts of the timbering; the other end, slightly sharpened, is against the heavy planks, called lagging. The pressure of the walls upon the planks gradually forces them out, and the spraggs go steadily through into the rock behind. When the planks reach the post the men in charge take picks, relieve the pressure, and put in new spraggs. This system keeps the main timbers from being broken.

We have thus studied the toils and adventures of the citizens of the real Comstock, the men of shafts, drifts, winzes, and ore chambers. This strange hidden realm begins to take shape in one's mind. It is truly a city, but it is not like the cities of the surface, nor can it be even measurably described by the terms and phrases that apply to such cities. If the California and Consolidated Virginia mines could be taken out of the great lode and set on a plain, they would cover a parallelogram thirteen hundred and ten feet one way and about three thousand

feet the other. The height to which they would rise would be over three thousand feet.

Through the mass around and within it one would see so many galleries and pathways that to remove the whole body of material piecemeal would seem easier than to construct a tithe of them. Everywhere there are angles, curves, and irregularities, as veins of ore have been followed. Everywhere the mass of soft, mineralized matter mingled with hardest rock is bored, patched together, upheld by braces, and kept from instant collapse. These mines, moreover, are only two out of many. The whole lode, if plucked forth by the roots, would present similar characteristics, and, more than this, it would lean like the Pisan tower, and the sides would run in and out like a toppling, wave-worn cliff full of coves and promontories.

But the Comstock seems to me a more impressive fact just as it stands, walled in by mountains and rooted so deep that men may toil there through centuries to come without reaching the bottom of its " fissure vein." After meditating upon the paths, lanes, alleys, roads, crossroads, and highways of the great group of mines, rising by stairs on stairs, from level to level, one is ready to grasp the completed conception of the labyrinthian wilderness, where, in the midst of abandoned acres of caves, pitfalls, and jungles of fungi-overgrown timbers, lie masses of ore and yet-undiscovered bonanzas.

Imagine, then, a city built by fallen angels or by the jinn and genii of Arabian legend. They have riven the Himalayas, the roof-ridge of the world, and in the vast cleft they have builded with stones and metals, cell by cell, as the honeybee builds. Millions of years the dwellers have toiled until the cleft, from palm-land levels to where deodars grow in the edges of snowdrifts, is full and running over. At last the kingdom of the genii

is overthrown by some superhuman hero. Wrathfully, then, the defeated ones rain fire and molten rock down the Himalayan cleft, pile mountains overhead, and pass, black-winged, out of sight forever! Still, traditions of the wondrous city live on in singers' tales, mingled with stories of heroes and the gods in their high places; still, men's imaginations cling to the legend. Then, in the fullness of time, treasure-seekers come, tracking up a barren cañon the faint spatter of molten drops blown from towers of gold in the wondrous city's conflagration. They tunnel into the cleft, they sink shafts into measureless depths, still molten with rains of fire, until they find and empty the palace rooms of the princes and monarchs of a race that existed before the generations of men.

A DAY'S WORK OF A LOCOMOTIVE ENGINEER[1]

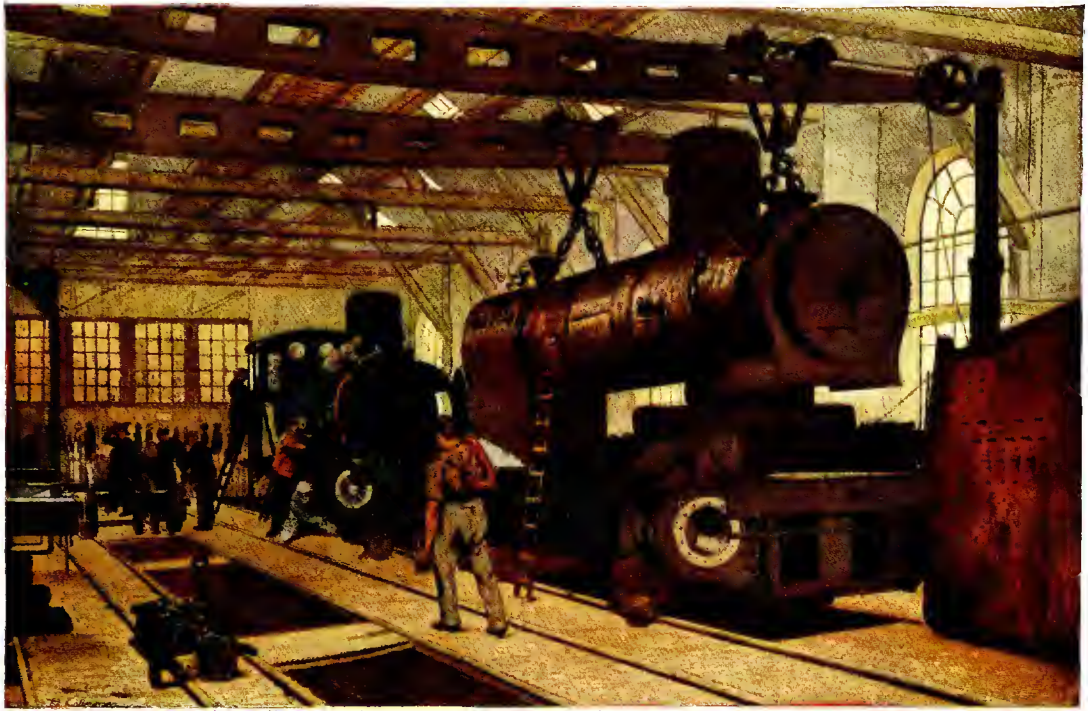
BY HENRY HARRISON LEWIS

THE little box-like compartment in which I stood was not much larger than a medium-sized packing case, and, moreover, it was perched high up on the side of a boiler which fairly sizzled with the heat. In front of the box was a stubby funnel which poured forth smoke and cinders in a never-ending volume, and behind, hardly eight feet distant, were two furnace openings that seemed to belch fiery blasts with every movement of the engine. In addition, it was a warm day.

I had one consolation, a very human one. On the other side of the boiler, in a compartment equally small and equally uncomfortable, was the engineer. His sole advantage over me was that he had long grown accustomed to his surroundings. His day's work caused him to spend from eight to ten hours of each twenty-four in this cab, which modern engine-builders had seen fit to attach to the hottest part of the boiler.

It was about three o'clock in the afternoon when the big Atlantic-type locomotive backed down to the train of luxurious parlor coaches. The engineer had brought her in from the yard, and when I joined him he was giving the oil-cups his final attention. He was a grizzled veteran of the throttle, with an unsullied record of forty-one years in one service behind him. In appearance he resembled

[1] From "The World's Work." Copyright, 1901, by Doubleday, Page & Company.



After the painting by F KALLMORGEN

A LOCOMOTIVE FOUNDRY

a New Jersey farmer with a predilection for the gold-bricks of the metropolis, but there was something in the intelligent gleam of his eyes and in the use of his words that stamped him as a man well read for his station, and one worthy of respect.

He knew his work, and he acted as if he loved it. He went over the many parts of the big steel monster with a skill born of long practice, poking the oil-can into little nooks and crannies, and touching rods and bearings with deft fingers. He noted, with a critical eye, a simmering of steam from the right cylinder and, plying a handy wrench, he cut off the leakage. He tapped at a spot on one of the big drivers, rubbed a bit of sand from a piston, filled oil-cups here and oil-cups there, and meanwhile talked to me.

"Been an engineer since 1860," he said. "I began when there was nothing but wood-burners, big flaming smokestacks, and all that, you know. On this same road, too. It did n't run to Chicago and goodness-knows-where in those days. Just straight through to Buffalo by way of Middletown and Goshen. Railroading was different then. Every engineer had to know how to take his engine apart between stations, if it was necessary, and how to patch anything, from a boiler to a headlight. We used to attend to our own cleaning, and, in most cases, to our own repairing. And when we went out on the road" — here he chuckled reminiscently — "only the good Lord knew when we 'd get back or where we would bring up. But here 's the conductor coming to swap time. We 'll leave in a minute or two."

The conductor, in his neat-fitting, brass-bound uniform, and the overall-clad engineer ceremoniously compared watches; there was a sharp, peremptory cry of "All aboard!" Then, as I climbed to my half of the hot-box,

resting like a pair of saddle-bags across the boiler, I heard the shrill call of the cab signal whistle. It was the command to depart.

Kent (" Eddie " he was familiarly called, despite his seventy-four years of life and his white hair) put the long steel lever far forward, to give the cylinders ample steam to start the heavy train. Then he pulled gently on the throttle. The rails were wet and slippery from the drippings of many boilers, and it required several efforts to make a successful start. As we rolled out from the shed Kent glanced ahead to where a great, gallows-like framework stretched across the tracks. On this framework were many upright posts, one for each pair of rails, and from each post extended a long wooden arm. That over the track along which we were slowly steaming presently dropped, and Kent gave the throttle another pull.

" That's one of our lighthouses," he shouted across the boiler. "And it's our compass, too. There'd be many a wreck if it was n't for those semaphores and the clear heads controlling them."

Out of the yard with its intricate maze of rails, out past interminable strings of cars, on, on, rolling ponderously over grade crossings, we went with increasing speed until at last the dark, yawning mouth of a tunnel suddenly confronted us. Kent sent an ear-piercing shriek of the whistle echoing along the rocky face of the bluff; then we plunged into darkness.

The sudden change from bright sunlight and the rumbling, creaking voices of the train in the narrow tunnel were startling to me, but it was evident that my comrade in the other half of the cab still coolly held to his work. I could hear the hiss of the air-valve as he released the brakes and feel the stronger impetus

of the mighty machine as he gave more power to the cylinders.

Presently there appeared ahead of us a dull, yellow ball of fire, glimmering in the darkness like a Cyclopean eye. It grew larger and brighter with great rapidity. Then with a roar it flashed past, dragging in its wake a score of little twinkling lights. A moment later we were out of the tunnel and were speeding across the Jersey meadows.

As she shook off the darkness of the tunnel our engine, Number 509 on the official list, bent to her task with renewed energy. Under the careful handling of " Eddie " Kent she gradually increased her pace until at last we were making a full fifty miles an hour. After a dash along a straight stretch of track, there came a temporary slackening of speed at a bridge; then an open throttle once more.

It requires only one ride with the engineer of a passenger " flyer " to realize that eternal vigilance must be his watchword. Keen eyesight, a clear head, and iron nerves are absolutely essential. For a certain number of hours each day his life is not only in his hands, but at the very end of his finger-tips. Danger lurks in every rail and in every switch-point. There is peril in the curves and in the cuts and even in the straight stretches of track. There is a real and separate possibility of disaster in every joint and tie, and a man to be a responsible engineer must have that fact in his mind from the minute he enters the cab to the end of his trip.

" You can't run an engine and saw wood at the same time," said "Eddie" Kent, in reply to a question. " You can't keep your head out the window and admire the scenery while your hand is on the throttle. And you can't dream or wink an eye, no indeed. In my run from

Jersey City to Port Jervis there are more signals than you think, and I 've got to see each of them in turn. And I 've got to know where there 's a grade or a curve or a bridge. And I 've got to know, all the time, that my train is under control.

" Yes, it 's true that engineers sometimes go all to pieces. They break down from sheer strain. It 's the curves mostly. A straight track is easy sailing, but when you reach the end of that straight track and the rails vanish beyond a bluff or a bit of a hill, and you are going a mile or so a minute, you don't know whether you 'll be able to keep on or pile up against something. It 's certainly wearing on some men. I 've seen fellows, big hearty men, who did n't know what a nerve meant, finally come back from a run shivering like a cat in cold water. Probably they had been pulling a throttle for years and had accidents, too. I 've read that it was because they had run over persons and were haunted by their dead faces, but it is n't so. It 's the dread of what might be there in the darkness beyond the rays of the headlight.

" No, I can't say I 've had that experience, at least not yet. Don't know why. I 've been running more than forty years, you know."

Kent's superiors say that the hale old man fears only his Creator, and that in his whole long term of service he has never received a scratch.

Engine 509 was comparatively new, and the track upon which she was running had been stone ballasted and coddled to a condition approaching perfection; but still the ponderous machine swayed and pounded like a tug in a seaway. There were few stretches of straight track after the larger towns had been passed, and on approaching the vicinity of Tuxedo the curves became even more frequent.

Engineers of Kent's long experience are almost invariably given a fast express; and local runs, with many stops and consequent greater work, are left to the newer men. On the time-table these fast expresses cover from fifty to eighty miles without a stop, except on signal at a few of the most important stations. The time allowance is cut to the lowest point compatible with safety, and the engineer is often compelled to run at breakneck speed when unavoidable delays have caused a loss of time.

We were eight minutes late passing Middletown, and as our train was an express with a record, the engineer of 509 felt called upon to recover as much as possible before turning the train over to his successor of the next division. As the last fringe of houses dropped behind and a stretch of country with few grade crossings opened out before him, Kent began to coax his engine. He brought the reversing lever into a more nearly upright position, so that all the expansive force of the steam would be used, and he opened the throttle notch by notch.

The effect was almost immediate. The puffs from the smoke-stack were no longer apparent: they had resolved themselves into one continuous rumble. The rattle of the speeding train was pitched to a higher key. Everything quivered and trembled as if the very heart of the metal was being taxed to the utmost. The fingers on the different gauges danced nervously. Through the partly open front door of the cab a gale of wind swept, carrying minute cinders which stung the face and hands like needles.

Still Number 509 was not going fast enough. Kent presently dropped the lever forward two notches. The massive engine responded instantly, leaping forward like a greyhound released from the rope. The terrible pace created a suction that caught up the dust and gravel of

the road-bed and sent it swirling back in great clouds. The trucks and the drivers pounded the joints of the rails and the occasional switches like mighty hammers. The bell clanged in its frame.

Kent drew in from where he had been leaning far out of the window, and snatched a hasty glance at his watch. He smiled with evident satisfaction, and, closing the throttle a couple of notches, shouted across the boiler:

"Made up six minutes, and with bad coal, too. I guess it's the best we can do, as we strike a heavy grade here."

The grade with its consequent stiff pull was followed by a long, winding descent. Steam was shut off, the labored breathing of the heavily taxed engine ceased, and, with one hand constantly on the air brake, Kent brought the train of parlor and buffet cars rolling gracefully into the station which formed the end of his westward run. Number 509, puffing and blowing, was turned over to the hostler, whose duty it is to take engines to the division yard for cleaning and inspection.

Several hours later Number 509; with Kent in charge, left for the homeward trip. It was now dark, and a raw, drizzling rain had set in. As the engine carefully picked its way through the labyrinth of tracks in the yard, it soon became evident that much which had made engine-running in the daytime an easy and generally pleasant task had vanished.

From the cab windows the fitful rays of the oil-burning headlight seemed to make the blackness even more intense. The rails, except for a short distance in front of the pilot, were invisible, but here and there little green or white signal lamps, indicating the location of switches or semaphores, served to guide us on our way.

The cab was in darkness, except for a partly shaded lamp burning in front of the gauges. Darkness was

necessary. The man at the throttle required no assistance in finding air brake or lever, but the absence of light in the interior materially extended the horizon of his vision outside.

Kent never took his eyes from the track, except to snatch an occasional glance at the steam-gauge. Leaning far out at the side window, despite the rain-shot gale which beat fiercely upon his rugged face, he kept vigilant watch for signal or sign of warning. The headlight, playing fitfully upon hillside or stony cut, upon bridge and track and level plain, gave him little aid. He felt that safety lay in the quick grasp of his hand upon the air brake and in the constant guarding by track-walker and watchman of every inch of the road.

At stations, where the stop was of any duration, he went over his engine with oil can and wrench, and was not content to leave until he was certain that all was well. Thus carefully he brought the train under his charge over the road until at last a dull glow in the eastern sky, the reflection of the lights of a great city, proclaimed the nearing of the destination.

The last fringe of hills was crossed; then the wide stretch of salt meadows bordering the Hackensack gave level running. By now the several tracks of the road had broadened out into a score. Other railway lines were encountered and still others lay before us, some crossing diagonally and some at right angles. It was a perfect maze of tracks, and Number 509 proceeded cautiously. The entrance to the tunnel through which we had passed that afternoon was a short distance ahead when suddenly Kent shut off steam and plied the brakes. A little twinkling red light surmounting a semaphore was visible just in front. Kent whistled vigorously and presently the red spot became white.

There was a hissing of air brakes as they were released throughout the train and we rolled onward with increasing speed. A minute later, or maybe two, I heard a sharp exclamation from the other side of the cab, then came a grinding, jolting sensation as the metal shoes of the brakes clutched the wheels with all the power of the air, and then, with a crash of splintering wood and rending metal Number 509's boiler head and pilot disappeared in the side of a box car, part of a freight train, which, unseen by us, had just started to cross our track.

The speed of the passenger train was sufficient to carry the engine half way through the car, and there it stopped with a tangled mass of débris hanging on both sides of the partially wrecked cab. The confusion following the wreck quickly subsided when it was ascertained that no lives were lost. The track was speedily cleared, and Number 509, assisted by another engine, limped into Jersey City with her train.

"I guess it 's all in a day's work," said Kent, as we shook hands on the platform, "even to my coming interview with the superintendent. I am not to blame. That light was white, and it will all come out in the wash to-morrow."

It did. The resulting investigation developed a most peculiar incident. The fault rested with the semaphore signal, which, despite its reputation for accuracy and responsibility, had displayed a white light where a red one had been intended. It seemed that a small bit of solder in a part of the mechanism had melted under the heat of the lamp, thus allowing the arm to drop and expose the white light.

The occurrence was beyond the anticipation of human thought, and it was philosophically accepted by the men of the throttle as one of the many picturesque incidents making up the day's work.

MAKING BIG GUNS[1]

By LIEUTENANT-COMMANDER ALBERT GLEAVES, U.S.N.

EVER since the days of Edward III the gun has steadily developed until it has grown from the tiny cannon, throwing a three or four-pound stone ball a few hundred yards, to the imperial sixteen-inch gun, capable of hurling a ton of steel a distance of twelve miles.

The development of gun manufacture in the United States, however, began not quite twenty years ago. During the Civil War our ordnance was not greatly improved over that of 1812, and the guns of 1812 had advanced but little since the immortal fight of Flamborough Head. Gun-locks and shell had been introduced, it is true, and rifling and breech-loading were to a less extent employed, but the standard navy guns from 1850–51 to 1877, or thereabouts, were the smooth-bore solid cast-iron Dahlgren "beer-bottles," as the sailors called them, burning nine pounds of powder and firing a projectile of about ninety pounds. A very few of these are still afloat, but they are as antiquated to-day as the old-fashioned carronades were in 1860.

After the Civil War, and during the transition period of our navy, an attempt was made to convert the old eleven-inch Dahlgrens into eight-inch rifles by inserting a rifled tube into the bore, but the rapid advance in the manufacture of artillery abroad, and the entire revolution in the art of gun-making, soon rendered these make-

[1] From "The World's Work." Copyright, 1903, by Doubleday, Page & Company.

shifts obsolete; so that as late as 1884 the United States was entirely destitute not only of modern artillery, but also of the means of manufacturing it. The only rifled guns we had were the muzzle-loading converted eleven-inch Dahlgrens and the sixty-pounder breech-loading rifles converted from muzzle-loading Parrots.

As this state of affairs was intolerable, in 1883 the President sent abroad a Board of army and navy officers to investigate foreign methods of gun-making. After a close inspection of the gun factories in England, France and Russia, the Board submitted a report in February, 1884, which resulted in the establishment of the great naval gun factory at Washington and the army factory at Watervliet on the Hudson.

The site selected for the naval foundry was the old navy-yard on the eastern branch of the Potomac River, by which the yard has direct communication with the sea. Here in the old days anchors were forged, ships built and fitted out, and guns fired and tested, for the Washington yard has always been identified with naval ordnance. Here also Dahlgren labored in his favorite field, and, dying, bequeathed to the yard the arm of his son Ulric, which lies buried in the walls of the old foundry.

During the Civil War the yard became a sort of fortified arsenal, and the scars of the loopholes with which the north wall was pierced when old Jubal Early halted within sight of the Capitol may still be seen. Here, too, the remains of Ellsworth were brought at the beginning of the Rebellion, and those of Wilkes Booth at its close.

It was a simple matter, in beginning the new work of establishing a gun factory, to eke out the one million eight hundred thousand dollars allowed as a starter by building upon the skeletons of the old shops; and then, year by year, as Congress loosened the purse-strings, to

supersede the old buildings altogether. The result is the finest group of gun-shops in the world — not excepting those of Krupp. They cover forty-seven acres of land, and are splendidly capable of making every class of gun, from the graceful thirteen-inch barker of the torpedo-boat destroyer to the ponderous thirteen-inch thunder-makers of the battle-ships, not to mention multifarious accessories.

Visitors there see in contrast to the guns of to-day ancient trophies guarding the outside of the big gun-shop. Guns which frowned upon our infant navy from the castles of the Bashaw of Tripoli, brass field-pieces from the plains of Mexico, and the famous "Long Tom" of the brig "Armstrong," which once wrote history in letters of fire in the harbor of Fayal — all these and many more border one side of the main avenue of the yard. In their day of glory, each in its degree was the last word of kings, but if put together in a crucible they would scarcely produce enough metal in weight to make one shot for a twelve-inch gun of to-day.

On the other side of the avenue the main gun-shop stretches over one thousand feet. Here the massive hoops, bands and tubes are delivered rough and rusty from Bethlehem or Carnegie's, and in due time,— eight months or so,— after a severe process of trimming and pruning in more than two hundred machines, they are converted into the shining rings and barrels which, when put together, make the finished gun. For, as every one knows, the modern "high-powered gun" is not made of a solid piece of metal, but is "built up" by shrinking around a central tube layers of massive steel rings in such a fashion that when completed the profile suggests an enormous drawn-out telescope.

In the early days of our gun-building, when the gun factory was a new toy, "shrinking day" always drew a

crowd of distinguished visitors from the upper end of Pennsylvania Avenue and the vicinity of Lafayette Square. Shrinking on a thirteen-inch jacket was a great event. Even now it never fails to excite interest.

The shrinking-pit in the gun-shop is forty-five feet deep, and when all its petroleum furnaces are aglow and roaring with the cold-air blast, every man of the six hundred in the gun-shop knows that soon there will be something happening. By custom, shrinking-hour is usually three o'clock in the afternoon.

"I am not superstitious," remarks the foreman, "but I have shrunk on eight hundred jackets in my time, and always at three o'clock, and I have never had an accident; so I don't see any use in changing the time."

It requires thirty-six hours of baking to bring the jacket up to its proper temperature of six hundred and seventy-five degrees or thereabouts, for it weighs thirty-four thousand pounds. When this is accomplished, the jacket is ready for its final resting-place over the tube. It is a liberal education in discipline and order to see how the workmen transfer the jacket from the pit to the tube. Every man knows his place and station, and not a word is spoken. The foreman conducts every operation by motions of his hands and fingers.

At his signal two overhead cranes, one with a capacity for lifting one hundred and ten tons, wheel over the pit. The smaller one hooks on to the lid of the furnace and swings it to one side, suspended in mid air. Then the big crane comes into position over the furnace and rapidly lowers its great shackle and chains to the jacket, where men with iron rods make the proper adjustments. When the shackles have hold of the jacket the foreman merely tips upward the fingers of his outstretched palm.

Immediately there is a mighty rattling and humming of the crane, and the jacket begins to rise out of the furnace. Wondering spectators grouped around the pit marvel at its length and size. When the jacket is clear of the furnace, after a moment's stop for a final wiping out with wet swabs on long poles, the craneman, with his eye on the foreman, moves the crane slowly along sidewise a few yards with its dangling sixteen-ton burden, until the jacket is exactly over the tube, which has also been placed upright in the pit. Now is the crucial time. Unless the jacket is exactly centered over the tube, it will bind when lowered, causing no end of trouble and expense and delay. As there is only four one-hundredths of an inch play all around, there must needs be steady eyes and steady nerves to guide the jacket fair. It is a breathless moment as the enormous cylinder is moved a fraction of an inch first in one direction, then in another. Everybody feels the strain, although the thing has been done and without accident a thousand times. The heat radiated from the jacket is intense, and the faces of the workmen who are steadying it with asbestos-gloved hands are red to blistering.

When the foreman determines that the jacket is centered he bends his fingers downward, and at this signal the craneman begins to unwind his reel and the jacket descends, very, very slowly at first, then with quickening speed, until finally it brings up almost with a drop on the end of the tube.

Eighteen hours are allowed for the tube and jacket to cool, the process being hastened by cold water circulated inside the tube. In cooling, the jacket contracts, and in contracting it nips the tube so firmly that it actually compresses it, so that the two practically become a single solid piece of steel. This is the principle upon which our

guns are built — technically known as "initial tension and varying elasticities."

This state of tension in a built-up gun may be graphically represented by slipping a tight rubber band over a stout cardboard bent cylindrically. The card is held from springing outward by the tension of the rubber, and, *vice versa,* the compression of the rubber is resisted by the outward pressure of the card.

After the "jacket" come the hoops, and gradually there grow around the central tube — which is the foundation of the structure — layers of great steel bands, until finally the gun begins to take a definite shape suggestive of its final form. Then the heavy cranes again take hold of it (weighing now about seventy-five tons), and place it in the powerful lathes, to be smoothed and polished, and bored and rifled, until the metamorphosis is complete and the ugly, unsightly masses of weatherbeaten metal have been ground down into the impressive peacemakers of the world.

While this marvelous evolution has been taking place under the glass-and-iron roof of the gun-shop, hammer and forge and slotter and miller in other shops have been ceaselessly doing their work in building the powerful carriages upon which the big guns must be mounted on shipboard. Three thousand men and a thousand machines share the work — work that must needs be skilfully done, for when the twelve-inch gun opens its mouth enormous forces are instantly released that must be immediately controlled, and the gun-carriages must be strong enough to absorb without failure a gigantic blow of forty thousand foot-tons. From the foundry where the big five-thousand-pound brass castings send up their fountains of fire, to the forge where the seventy-five-ton hammer throbs and makes the ground tremble with its

giant blows, night and day without ceasing the work goes on — this grim work of preparation for war in order that peace may prevail.

Although in point of material fact the broad ocean is nearly two hundred miles distant from the navy yard, it really is much closer. The voice of the sea is heard in every gun, and its mysterious influence is more or less felt by every man in the shops. When the war was on with Spain, the mechanics of the Washington gun factory rightly felt that they also served, and, indeed, there were no men under the Government who worked harder or more patriotically. They were the men who made the guns; by virtue of priority of service they felt at least the equal of the men behind them. Indeed, the connection between the fleet and the factory is so strongly felt that not infrequently men and boys yield to the "unseen reality" and enlist in the navy for service afloat.

Such, in brief and most general terms, is the gun factory and its method of fabrication. Since work was begun there in May, 1887, one thousand two hundred and ten guns of various calibers have been completed, and two hundred and eighty-one were in process of manufacture in 1903. The expansion in the volume of work performed at the gun factory is shown by the fact that the annual expenditure for labor alone increased from one hundred and seventy-seven thousand three hundred and twenty dollars, in 1884–5, to one million seven hundred and forty-six thousand one hundred and sixty-eight dollars, in 1901-2, or nearly tenfold. In 1891 there were in use in the gun shops four hundred and five machines driven by engines aggregating one thousand five hundred and thirty horse-power. In 1902, the total number of machines in the shops was one thousand two hundred and twenty-three, the horse-power six thousand, one hundred

and thirty-six, or an increase in power alone in ten years of nearly five hundred per cent.

The proving grounds at Indian Head, on a Government reservation, twenty-three miles from Washington, are a necessary adjunct to the gun factory. These grounds are primarily for the purpose of testing guns, armor plates, and powder, but the scope of the work has been extended to include a smokeless powder plant. After "proof," the guns are returned to the gun factory, where they are finally inspected; they are then shipped by rail to the ships for which they are intended.

Ships are built to carry guns — that is to say, ships are simply gun platforms furnished with motive power for transportation and mobilization.

As the life of the ship depends upon her heavy guns, these must, in the first place, be thoroughly inspected, and they must also be so placed as to obtain as large an arc of fire as possible. To this end they are mounted in pairs in heavily armored steel turrets. Each turret can be trained through two hundred and seventy degrees of the horizon. The eight-inch turrets are disposed between the main turrets, while the seven-inch battery is located on the deck below in armored casements. The small guns are distributed on the bridges, along the decks, and in the fighting-tops. The concussion of the explosion of a twelve-inch gun is tremendous, but no disagreeable effect whatever is experienced by those in the turret. From "gut to thigh" the monster roars and trembles, but the noise is all outside. The gun, however, recoils in the turret with a speed of five and one-half feet per second, with the tremendous energy of more than forty-six thousand foot-tons, but so cleverly is the mount designed that this marvelous force is checked in a distance of thirty-six inches by absorption in heavy steel

THE JACKET OF A BIG GUN

springs, which immediately return the gun to the firing position.

The first question one usually asks in regard to a gun is, How far will it shoot? But with the artillerist, range is not the measure of efficiency; the question rather should be, How much steel will the shot penetrate? As a matter of fact, the twelve-inch gun will easily shoot a distance of nine miles. Standing behind the gun, it will require not a little practice to follow with the eye the projectile in its flight. If the gun be elevated to twenty degrees, the projectile will be seen as a black speck to rise one mile above the earth before it begins to descend, and if the observer has a stop-watch he will find that the shell takes just forty-two seconds to travel the nine miles — a velocity sufficient to girdle the globe in less than thirty-three hours. It is more to the point, however, to know that with three hundred and eighty-five pounds of smokeless powder, the new forty-caliber twelve-inch gun will send an eight-hundred-and-fifty-pound armor-piercing shell hurtling through nineteen and five-tenths inches of Harveyized nickel steel armor at a distance of three thousand yards.

THE WEB-FOOT ENGINEER[1]

By BENJAMIN BROOKS

WHILE the "tallest building in the world" — which is always being built somewhere in New York — continues to absorb popular wonder and attention, and the great cantilevers, and suspension-bridges continue to bear up under their weight of criticism without visible means of support, the most important but least spectacular individual concerned in their existence continues his unobtrusive subterranean operations almost unknown, except as he may from time to time annoy us with the blocking of a thoroughfare or the creation of a local earthquake. Thus, the term "skyscraper" is an old one, while the term "earth-scraper" was invented but yesterday.

I have spoken of this retiring person as web-footed because, as with ducks and cranes and other animals thus endowed by nature, the business of his life is in the mud, the shifty quicksand, and under water; and whatever he may lack in the spectacular or picturesque, he is nevertheless most worthy of notice for his unequaled ingenuity.

The web-foot engineer has three main problems to deal with: to support a tremendous weight over soft mud or quicksand; to open and maintain a clear passage through it; to drain it off and eliminate it altogether. Out of these three main problems grow an endless combination of difficulties that he must devise means of overcoming; but in all of them enters his arch-enemy, water — water, the basis of all big engineering, locater of railways and

[1] By permission of "McClure's Magazine." Copyright, 1909.

thoroughfares, distributor of population, maker of treaties, destroyer of man's half-baked, faint-hearted attempts, but conserver of his truly great works.

There is an old, shop-worn fallacy that the great man is always at hand awaiting the occasion that will bring him out of oblivion and put him on his mettle; but the two greatest cities in the world both waited years in an over-crowded, river-girt condition, loudly proclaiming the occasion for a great man; yet it was a long time before he came to liberate them. He appeared early in the last century to the city of London after that town had overflowed its bridges for generations, and he presented a scheme for driving a tunnel under the Thames through the comparatively soft clay.

Everybody knew that so large a hole as a tunnel could not be dug and kept open under the Thames; but if a short, portable piece of completed tunnel could be continuously pushed ahead and added to from behind, what then? He conceived a steel contrivance just a trifle bigger around than the tunnel was to be, shaped in about the proportions of a baking-powder can, with no bottom and no top, but having a diaphragm or partition across the middle of it. When this had been sunk down and started on the line of the tunnel, the forward part of the shell would hold up the overhanging mud sufficiently so that men could work through little doorways in the partition, digging the earth from in front and loading it into cars to be carried out behind; and at the same time, on the interior of the after portion, other men could bolt together the steel or iron sections of the tunnel lining.

A short section having been completed in this manner, the whole machine could push itself ahead with a kick — that is, with powerful hydraulic jacks pressing against the completed part of the tunnel. Imagine having forced

a large, empty sugar barrel horizontally into a bank of earth, first having knocked out both heads. By crawling into the barrel a man could, with considerable discomfort and perspiration, dig away the earth some little distance in advance of the barrel, and, given something to kick against, he could push himself and his barrel farther into the cavity he had dug. Now, if another man were to hand him the necessary staves and *internal* hoops, he could build a second and slightly smaller barrel partly inside of the first one. He might then do more digging and more pushing ahead, until he had proceeded far enough to build a second small barrel and fit it tightly to the end of the first small barrel. In this way, since a small barrel always lapped partly inside of the big one in which he worked, the earth could never cave in and cut him off from daylight; and as long as he was provided with staves, hoops, food, water, and air, he could burrow on indefinitely.

Such, in a nutshell, was the idea of a certain web-foot engineer, Sir Marc Brunel, in 1824, — the simplest, best, most ingenious idea that has occurred to engineers in many years. The great cities had waited for it so long that they accepted it ravenously. Tunnels burrowed under the Thames, the Seine, the Hudson. Poor old tunnels that had set out without it and gone bankrupt at the discouraging rate of a few inches a week, took on a new lease of life and set out again at many feet a day; and they are going still — all day and all night, steadily, blindly. but surely, on under the rivers to set the cities free.

Of course the original idea has to be modified somewhat for every particular tunnel and for each variety of mud. If the mud is full of gravel and boulders, the forward half of the machine has to be worked under compressed air

to balance the pressure of earth and water; and the workers have to be provided with safety locks in case of a sudden inrush of water. If you invert a glass in a bowl of water and press it down, the water will not rise to any extent in the glass. On this principle, little inverted steel pockets are made for the men to retreat into in case of accident and keep their heads above water until assistance can come.

If, on the other hand, the earth is tough and regular, instead of being dug out by miners the way is cut automatically with a large rotary cutter. If it is softer still and too mushy to be counterbalanced by compressed air, then the top of the forward shield is made very long, so as to let the mud cave in on a long slant and still not fall from above. When it gets to the consistency of porridge, as it is at the bottom of the Hudson, it is found possible to force the shield ahead without any digging, merely letting the mud ooze through the partition doors and shoveling it into the cars. At times it was thought possible to force ahead without opening the doors at all — merely pushing the mud out of the way; but this was too simple to be strictly according to the rules of the game, and the obstacle presented itself that the extra weight of this overcrowded mud was enough to lift or float the whole tunnel up out of its proper alignment.

Again, in the Boston Tunnel, the mud was so accommodating as to stand up almost without support, so that the whole machine was reduced to a simple steel arch on rollers without any partition at all.

Another of the web-foot engineer's problems — to support a great weight on or over mud — would seem to be simpler than the under-water tunnel problem; and, up to a certain limit, it is. If the soil is capable of holding only one ton on each square foot, and a certain column

is to sustain five hundred tons, all one has to do is to spread out its base by crisscrossed steel beams and concrete slabs to the extent of five hundred square feet — if one has the room; and if the adjoining columns are close enough to it so that their bases touch, you have your structure floating on one continuous slab. Nothing could be simpler or easier — unless some other man with an equally heavy structure to support comes to excavate a foundation alongside of yours, and the mud runs out from under you.

This brings us to the ancient expedient of pile-driving. Many thousands of years ago the more ingenious and weaker part of the population of central Europe maintained itself against the more warlike and less mechanically skillful part by building itself pile villages out over the lakes. And the stumps of the piles on which Caesar crossed over the Rhine are still to be found, in proof that his luminous Commentaries are not fiction; yet, even in this late day, the science is still young, and every few months bring forth an improvement in the making and driving of piles.

In fact, so perverse and unexpected is the behavior of piling that I doubt if it can ever be reduced to a science. For instance, you may drive a ninety-foot pile into soft river mud so easily that it will fall of its own weight to a penetration of twenty or thirty feet, and go indefinitely two or three feet to the blow of a fairly heavy hammer; and, having driven it, you may immediately hook a line to it and pull it out again. But allow it to remain driven for an hour or so, and you may sink a forty-ton barge and break every line in your outfit trying to budge it. Similarly, you may pound for an hour on the unfortunate head of a pile that penetrates quicksand. A horse or a man could not stand for a minute on the spot without sinking

out of sight; yet the pile, as if being driven on a rubber buffer, will bounce stubbornly under every blow, but sink scarcely a hair's breadth. Moreover, having, in the course of a long and discouraging day, succeeded in getting two or three bents down to a minimum depth, you may return next morning to see your whole day's work floated up and out during the night and idly sunning itself on a sand-bar a few miles downstream. Yet if you were wise enough to run a long pipe down by the pile as it was being driven, and keep a stream of water forced down through it to bore away the sand, you would find, immediately on withdrawing the pipe and stopping the water, that the pile was stuck fast, there to remain forever. Nobody knows how much a pile of given length and girth will bear till he tries it; but the holding power as compared with any spread-out surface footing is enormous.

It unfortunately happens, however, that although a sound stick of timber will remain such in thoroughly wet earth for ten thousand years, it can not be trusted to last ten years in dry soil. Furthermore, if it stand in salt sea water, that harmless-looking but very costly white worm, the teredo, — which, although neither ugly nor venomous, wears a boring-mill on its head, — will certainly make short work of it. Ten months in temperate water is all he needs to make honeycomb of the best stick of pine that ever grew.

To prevent this destruction and decay, then, it is obviously necessary to stop all timber work underground, below the possibility of dryness; and this is what takes most foundation work out of the hands of the top-soil contractor and places it in the hands of the web-foot. There is always some place in New York, and most other large cities in America, where he is to be seen making day

and night and the neighboring property hideous with his smoking, pounding drivers and creaking derricks.

First, you see him taking great pains to build himself a water-tight dam of driven planks (he refers to them as sheet piling) or steel staves. Then come his bulky timbers as thick as a man's body, blocking the streets temporarily; and after these are placed, his ravenous bucket begins to bite out the dirt from the inclosure. Then his driver pounds down the piles that are to do the supporting of the piers, forcing them below the water, and driving them still farther with another short pile mounted temporarily upon their vanished heads. After this he has the choice of pumping out the water and sawing them off evenly, or of rigging a buzz-saw on a long, vertical, revolving shaft to cut them off under water. He has a like choice in placing his pier upon their heads.

With the water pumped away, he may make a dry-land job of it; or, leaving the water standing, he may lower the concrete in specially constructed buckets that remain tight until they touch bottom and then accommodatingly dump their cargoes without allowing them to be washed away; or he may drop all the concrete down through a steel or canvas pipe moved about over the pile-heads, or deposit it sewed up in bags. New Yorkers who habitually passed the site will remember seeing these piling and capping operations going on to make foundations for the then heaviest and tallest Park Row Building.

All these processes are delightfully simple to write down, but gray hairs and insomnia lurk in their actual doing.

Considering the courageous jump-off from all precedent and established custom that the web-foot engineer has had to make, it is not surprising to find that the "father of civil engineering" in modern times was himself a

pioneer web-foot. John Rennie was originally a mill constructor. But when the tide washed the foundations out from under his mills at Blackfriars Bridge he was forced into matters of a larger sort. He earned his title by draining off that part of England which the appropriately named River Ouse had made into a hopeless swamp (a job that baffled even the great Cromwell), thereby furnishing the first and best example of the web-foot's third problem, wherein, by a system of dikes and ditches, he "un-waters" the land and renders it fit for cultivation. The magnificent Waterloo Bridge across the Thames is also his work,— his monument,— and when one looks upon this and the adjoining massive structures, which better than anything else portray the true solidity and grandeur of the English people, it is hard to believe that they are all standing knee-deep in river mud.

Rennie has his engineering descendants in every large modern city — in almost every large project of any kind; but especially are they to be found in our tallest, heaviest city of all — men far more worthy to be proud of than the world's records they have broken, or the inventions they have made: J. T. O'Rourke, who proposed the first circular caisson and invented a way to remove the roof or partition immediately over Mr. Sandhog's head so as to render the concrete pier one solid piece instead of two; John W. Doty and Daniel E. Moran, who simplified it further, making the future concrete pier serve to sink itself and arranging trap doors of such lightning action that the bucket and its muddy contents make a trip every minute; T. Kennard Thomson, who designs the four-masted derricks, and whom I suspect of having everything to do with the speed records made in sinking caissons; Alfred Noble and Charles M. Jacobs, under whose supervision the East River and North River

tunnels were designed; Samuel Rea, who passed upon all the plans, and directed the entire work; E. W. Moir, who personally supervised its execution: to say nothing of the assistants and resident engineers — Harrison, Brace, Mason, Woodward, Japp, Manton, who "slept on the job," worried over it, perspired over it, dreamed of it in whatever sleep they were fortunate enough to get.

It is they whom I have respectfully termed web-foot engineers, who have transformed a small river-girt, rock-backed, swamp-covered scarcely habitable island, originally worth twenty-four dollars, into what is now, in some respects, the most livable, though in other respects the most unlivable, but at all events the most lived upon, most densely populated, richest spot under the sun.

MINING ENGINEERING [1]

BY ROBERT HALLOWELL RICHARDS

I WILL begin my story by attempting to show how universally the work of the mining engineer reaches the interests of all. I will then trace from early beginnings the development from the primitive chance find, of attractive mineral specimens, to the modern, fully equipped mine. I will show how the mine not only supplies wants of all classes but calls upon many lines to respond by contributing to mine development. And, finally, I will indicate the educational lines which are developed to bring men to as good an understanding as possible of how to get the most effective results in mining with the least expenditure of material and effort.

The province of the mining engineer may be defined as comprising all the duties and abilities that a mining engineer may be called upon to perform or possess, the end point of which is the extraction of valuable minerals and placing them on the market for the service of man. He brings from the ground into active use values which previously lay dormant and unknown to the uninitiated. He builds, out of apparent nothingness, things which eventually make for use and beauty in the service of men. He has, therefore, wide ethical and philosophical relations with the development of the human race.

Looking back through the eye of the imagination to prehistoric times, we may form a conception of an order

[1] From "Congress of Arts and Sciences." Copyright, 1906, by Houghton Mifflin Company.

of advance in things mining. The primitive man picked up colored stones, bored holes in them, and wore them as amulets for decorative, religious, or medicinal reasons. He found the precious stones and prized them for their decorative effect. He found the gold in nuggets, and later discovered that he could polish, flatten, and shape it, and thus made a beginning in the metal manufacturing art.

Gold and precious stones at a very early date must have risen in value and begun to be property, and also begun a career as a medium of exchange. A complete mining plant at this time may have been an area of land with ore specimens scattered on the surface of the ground and buried in the surface soil, with a few men digging with pointed sticks and moving the soil with rude wooden shovels. The existence of ownership in the soil and mineral may have developed later.

Stimulated by mineral discoveries, the miner made efforts to define, identify, and name his mineral species and so gave a beginning to the science of mineralogy; and his efforts to establish rules of occurrence of his valuable minerals did the same for geology.

The primitive Asiatic at an early date found the effect of fire on minerals and picked up lead, copper, or iron in the ashes of his camp-fires. Cornwall tin was found in the same way.

The primitive metallurgist then experimented with his fires and got silver by burning up his lead, and bronze by alloying copper and tin.

The possibilities fascinated him, the getting stimulated the desire to get, and the ingenuity to fashion the tools to get with. In fact, the metallurgist has done much to stimulate the development of the chemist. There came to be a systematic use of fires for roasting ore, reverberatories

for desulphurizing ore, crucibles for melting, cupels for purifying silver, hearths and shaft-furnaces for smelting.

The miner, pushed by his metallurgical partner, soon got to the end of the loose ore lying on the surface and began breaking it from the ledges with his stone hammers. He found that by heating the ore and quenching it with water it would crumble more easily. In fact, this was probably the chief method of mining for many centuries.

A mine at this period may have been a pit or trench twenty feet deep, more or less, from which the ore and water were carried out on men's backs, using a tree with stubs of branches for a ladder.

In time the metallurgist found that by manipulating his iron in connection with carbon he could harden it and that the hardness was greatly augmented by quenching it in water. He had made the discovery of steel and of tempering.

The miner asked for a better hammer and got one of steel, and with it the "point," which, by blows of the hammer, chips and severs the ore from the ledge. The hammer and point, "Schlegel and Eisen," must have been the standard mining tools for many centuries.

The primitive American mined copper at least five hundred years before the discovery of this country by Europeans. They mined the copper with stone hammers, heating the rock with fire to make it more friable. They mined to a depth of twenty or thirty feet, but rarely went underground; used wooden shovels to move the rock and wooden bowls and bark troughs to dispose of the water. They did not want and could not use pieces of copper larger than a few pounds, which they took as they found them, beat out cold into shapes, leaving the silver attached to the copper. They apparently had no knowledge of concentration or of smelting. They used the copper for

tools of the household, of the shop, of the chase, and of war, as well as for decorative purposes.

The making of iron tools enabled the miner to penetrate into the ground. He devised ropes, buckets, and a rude windlass for lifting out ore and water. His roof and walls of rock began to fall in on him and it was necessary to bring in timber props and to leave pillars of ore to hold the walls apart.

About this time the horse-windlass and a better quality of rope must have been designed for hoisting from greater depths. Mines at this time may have reached a depth of hundreds of feet with tunnels and galleries, though small in size, yet cut out with a care and finish almost like that of the stonemason's work on public buildings. Such tunnels of three hundred years ago can be seen to-day in the German mines.

The metallurgist asked for cleaner ore, free from earthy and siliceous impurities which hindered or prevented his smelting operations; to effect this, the crude stamp for crushing, and the sweeping buddle for concentrating ores were developed.

The next great step was the use of the drill and blasting powder (1620 A.D.). The slow, tedious chipping was replaced by the more rapid boring and blasting out of rock masses, and the speed of mining increased immensely. In 1776 the steam engine came to the help of the miner. The pumping engine came first, for removing water, and then the hoisting engine.

About 1840 the locomotive was invented and used for hauling coal and ore.

We sometimes think of all engineering as depending on or pertaining to the steam engine, whereas the true engineer is a man who must adapt means to ends, whatever they may be, and whether he ever did, or did not, know

of them before. He can use precedent as far as it will go, and must fill in the rest from his brain. He may have to harness up a waterfall on the side of a mountain, bring down the water in a great pipe, and level gravel hills with a water jet more powerful than those used by our city fire departments. Or he may have to use the water to compress air and convey it in pipes to his mine and use it there to drive his powerful hoisting and pumping machinery and his power drills for drilling the rock.

In 1860 nitro-glycerine was introduced as a powerful blasting material, adding to the speed and economy of the work of excavation.

The miner, by his needs of prime movers, transmitting machinery, transporting machinery, and use of water, has contributed much to the development of the mechanical engineer and to a less degree to the railroad and hydraulic engineer.

The miner and the agriculturist really take shares in this development. They are both fundamental callings, taking the good things from the ground. The farmer has probably helped more in the development of the railroad, while the miner's field has given him a greater hand in developing power machinery and hydraulics.

Later, these all became independent professions, and having made great advances in their studies they now in their turn contribute advanced ideas to the benefit of the miner.

But here again no mining engineer can afford to be without a good working knowledge of mechanical engineering, constructive engineering, hydraulic engineering, or railroad engineering.

This brings us to the great mines of to-day such as the Calumet and Hecla Mine of Lake Superior, which will, perhaps, serve for purposes of illustration as well as any.

This mine exhibits both what is primitive and what is most modern in mining practice. It was discovered by a prehistoric pit, evidently worked by a race of advanced intelligence before the Europeans reached this country, and it is now equipped with the finest mining machinery in the world. To-day it is opened up by some fifteen shafts, more or less, on the slope of the deposit, which are about four hundred feet apart. The longest shaft is opened about eight thousand feet down the slope. A vertical shaft nearly a mile deep connects with this below. Every one hundred feet, going down, there is a level or horizontal tunnel driven along the deposit either way, and these one hundred by four hundred feet blocks of copper-bearing rock are worked out by drilling and blasting with dynamite. The roof is temporarily supported by carefully designed timbering, which holds up the roof until the rock is all worked out, and then gradually crushes, letting the roof fall in. Every one of the levels has been carefully surveyed so that they will properly connect with each other and the ends will not go beyond the boundary-lines, and they are supplied with a railroad track and cars. Every shaft has been surveyed and supplied with a track for the hoisting-skip and a hoisting-rope; at the top of the shaft is a rock house with two immense rock breakers, two great sheaves for turning the hoisting rope and a hoisting engine powerful enough to lift at great speed the rope skip and copper rock, weighing many tons, to the surface. Beneath the breakers is a great rock bin and tracks for shipping the rock down to the mills at Lake Linden, five miles away.

Several great air compressors furnish air for the rock drills operated by three thousand miners, more or less, producing five thousand tons or more of copper rock per day.

The mine has water works bringing the pure water of Lake Superior up to five hundred feet in height, four miles in distance, to supply the boilers and also the company's houses.

A huge revolving fan uses one shaft for ventilating the many miles of shafts, levels, and stopes, giving the miners fresh air and removing the powder smoke.

The mine has machine-shop, foundry, blacksmith-shop, and carpenter-shop, capable of doing the finest work on large or small scale.

Going to the mills at the Lake, we find two large mills with about eleven steam stamps each, twenty-two in all. Each of these stamps can crush nearly three hundred tons of copper rock per day and each has a large number of jigs, Wilfley tables, and revolving tables for concentrating the crushed rock. They appear like monster factories filled with busy machines, and treat between five thousand and six thousands tons of copper rock per day.

There are two immense pumps lifting a quantity of water, sufficient for one of our large Eastern cities, for the mill work.

The shops of the mine are in the main duplicated at the mills. An idea of the importance of this mine to the people may be obtained when it is stated that the Calumet and Tamarack mines together support a population of about thirteen thousand, and the mills about five thousand more, speaking some seventeen different languages. They have their schools and churches, and furnish a market for farm and garden produce. All of this would not have existed but for the mines.

The development of gold placer-working is of interest and deserves special mention. The miner washed his sand or gravel in a pan; settling the gold to the bottom, and working off the gravel over the edge, he recovered a

few particles of gold from each panful. It was back-breaking work, and he could perhaps pan only a few hundred pounds per day. The rocker or cradle with little depressions or riffles followed with two tons per day, the tom or little sluices with riffles with ten or twenty tons, the riffle-sluice with a capacity measured only by its width and the quantity of gravel that could be brought to it. The increased quantity was obtained by the giant or jet of water issuing from a nozzle five to nine inches in diameter under a head of two hundred to a thousand feet, capable of moving thousands of tons of gravel to the riffle-sluice several miles long, saving many thousands of dollars of gold.

At this stage an opposing interest appeared in the farmer on the low land whose river was filled with débris and whose farm was flooded with water. To overcome this difficulty, various schemes of retaining-dams were devised and found, to a very limited degree, successful. Later came the dredger, which for certain deposits holds the field to-day. It is a flat-boat floating on its own little pond with a chain-bucket dredging-tool at the bow, a screen and riffle-tables to save the gold, and a stacker or elevator to pile up the refuse at the stern. This boat performs the curious feat of traveling across the country carrying its pond with it, cutting away the gravel in front and building it up behind. These dredgers mine, for about six cents per cubic yard, two thousand yards per day, and the gravel may run from ten cents to one dollar per cubic yard.

The dredger is self-contained, saves the gold, and does not infringe upon the rights of the farmer.

And so through the various stages, the development of mining has gone on until we have the large modern mine equipped with fine machinery for excavating and tram-

ming, those with powerful hoisting engines for lifting hundreds of tons from thousands of feet in depth, with great ore-breakers for crushing the rock, and fine concentrating machinery for enriching the ore; furnished, also, with monster pumps for removing the water from great depths and with concentrators and fans for taking out the powder and smoke and other dangerous gases, preserving the lives of hundreds of men; presenting problems for the mechanical engineer in the handling of great masses of material with rapidity and economy; problems in surveying the most difficult the civil engineer has to encounter; for example, to fix exact property boundaries or to unite subterranean galleries thousands of feet below the surface, and in hydraulics to handle immense volumes of water to be made use of or to be got rid of, and in electricity to effectuate the transmission of power many miles from distant mountain streams; to excavate, tram, hoist, pump, ventilate, and light the mines; to construct great buildings for housing his machinery or his plants; to adapt crushing and concentration plants for the most successful treatment of the ore and problems of smelting; to extract the metal with the least cost and greatest efficiency and purity.

Mining also comprises the wise selection of subordinates for efficiency and loyalty; the handling of the men to get a day's work and keep them contented and happy; the financing of the mine to get the money for opening up and developing, to keep up the dividends and the repairs and development work and sinking fund, all at the same time, so that the owners may feel that they receive a satisfactory interest on their investment and get their money back after the mine is worked out.

This completed picture seems to call for a combination of mineralogist and geologist, of a mining, mechanical, civil,

and electrical engineer, of a chemist and metallurgist, of a builder, a manager, and a financier, a man with literary ability and personal magnetism. Such a combination seems impossible of attainment and yet it is not unknown in actual life.

Mining enterprises occur of all sizes. In the small mining venture the mining man must be able to handle all the departments specified; while, on the other hand, in a large mine he has many departments with department-heads, mechanical, civil, and electrical engineers, builder, chemist, and others, but he has to direct all, so that a good working knowledge along the various lines is quite as important in the largest mine as it is in the smallest.

The question may now well arise, On what lines and how should a man fit himself for this class of position? How can he best master this wide relationship of the mining engineer to the other fields?

I will attempt to answer this question in some detail. The accomplishments he needs are comprised substantially in this list:

English: He should speak, read, and write the English language well, to convey intelligently his plans and suggestions to his superiors, his wishes to his subordinates, and to read up his authorities on matters professional.

Language: He should know foreign languages for ease in conversing with foreigners and reading their works.

Literature: He should be familiar with good literature, to give him ease in meeting people to widen his intellectual horizon.

Logic: He should understand the basis of argument, the relations of cause and effect, both as to men and things.

Mathematics: He should be able to use mathematics for clear thinking, demonstration, and estimating.

Physics: He should be familiar with the laws of physics;

mechanics, heat, light, electricity, sound, pneumatics, hydraulics, to help him act wisely in professional matters.

Chemistry: He must understand the laws of chemistry, not only as to effects of humid operations but as to effects of fire.

Drawing: He must have a good working knowledge of drawing for clear thinking, for making designs, for expounding plans to others, and for directing work.

Power: He must know the prime movers in their operations, their economy, and efficiency.

Machinery: He must understand the transmitting machinery, to bring his power to the commercial end-point with the greatest economy.

Railroads: He must understand the laying out and running of railroads, including cuts, fills, tunnels, grades, tracks, switches, bridges, rolling-stock, locomotives for conveying his material.

Surveying: He must understand surveying for defining underground boundaries, for meeting underground workings, for locating, grading, roads, buildings, machines, water-pipes, ditches, wires, and the like.

Mineralogy: He must know and be able to determine the minerals of economic importance, to recognize and take advantage of values when and where opportunity occurs.

Geology: He must be skilled in geology for locating deposits, in preliminary work, and for predicting the whereabouts of ore-deposits in existing mines.

Materials: He must know the materials of engineering — what, when, where, and how to use them, and also to preserve them.

Structures: He must know the principles upon which structures are built and the practice in building.

Law: He must be up in the law of contracts and of titles, to see that his company gets its rights in purchasing

materials, selling materials, and in ownership of its property.

Labor: He must know the value of a day's work and see to it that his men know that he knows. He must study the labor problem so as to deal wisely with his laborers in the time of need.

Business: He must understand the principles on which business is transacted so as to get fair treatment and yet keep his customers.

Finance: He must understand the principles of banking, and of establishing and holding credit.

Mining: He must understand the mining operations safely to mine, prepare, and ship the ore or coal.

Metallurgy: He must understand the chief metallurgical operations for the common metals so as to suit the metallurgist with his ores or become a metallurgist, if opportunity and inclination lead him that way.

He will equip himself along as many of these lines as he can, and establish connections for supplying those which he has not acquired.

Let us now enumerate some of the contributions of the miner to the advancement of social well-being.

If we look about us, scarce an object can be seen to the production of which the miner and metallurgist have not contributed. Metal objects owe their strength to the iron or the copper alloys of the miner, their purity to the metallurgist, their beauty and decorative effect to gold, silver, brass, bronze, stone, pottery, and wood, all of them got from the mine or fashioned by metal tools from the mine.

Our carriages, automobiles, locomotives move us from place to place; our wires carry our telephone and telegraph messages; our sewing-machines make and mend our garments; our saw-mills make the lumber for our houses; our harvests of wheat, corn, and potatoes, our

pots and pans, knives, forks, and spoons for cooking and serving food, all, either themselves come from the hands of the miner, or the tools for fashioning or getting them are the result of his labor; our diplomatists after doing their all with their wits come as last resort to the battle-ship, the guns, the rifles, and the lead from mines.

And, finally, the medium of all finance with which we operate our mines and our factories, and with which we purchase our wares and supply our wants, whether for peace or war, is the gold from the miner's pick and shovel. We may say, then, that the work of the miner reaches the interests of all.

Coming now to the schools in which he is to prepare himself for his life's work: there appear to be three plans of education which deal with the problem of equipping men along mining engineering and metallurgical lines.

(1) The school of practice.

(2) The technological school.

(3) The college followed by the technical school.

Some pupils of all three plans reach the highest pitch of professional responsibility, as the secret of success is more a question of the man than of the plan. We have no reliable statistics showing percentages of success or of proportional success.

The especially strong point in the first plan is the intimate knowledge that is acquired of the employee class and of minute details, of practice — knowledge of work which is obtained in the doing of it.

The especially weak point in the first plan is that it is narrow and that progress is slow. Experiments may be more expensive to the company and, in consequence, a greater conservatism rules and a lack of readiness to adopt new ideas even when proved valuable elsewhere.

The second plan has the advantage that in four years

from the high school the student is equipped and strengthened along a sufficient number of lines so that he can do the rest if he is reasonably energetic and sensible. He may fail because he has not made a sufficient study of the employee class. He can easily avoid this, however, by taking hold of manual work as a laborer or a miner for a sufficient time to acquire the knowledge of what men are, what they do, and how they do it. He may fail because he has not made a sufficient study of how to deal with men who are his superiors, or of the capitalist class. This he can avoid if he will accept every opportunity to meet men, and keep himself well informed on the progress of his profession and on affairs of public interest, and widen his horizon by the reading of good literature.

The third plan takes six, seven, or eight years from the high school and may lead to crystallization of the man even to the point of inability to adapt himself to the demands that will be made of him. This is the weakest point of this method. His best prevention or cure will be to take hold of work as the laborer and miner and make an intimate study of the employee class by doing the work side by side with them. In regard to the professional work, the third plan may or may not have an advantage over the second in consequence of maturity. The logical advantage may be offset by the time lost and by hurtful crystallization. "The college student may have learned to do nothing thoroughly well, and if he enter the scientific school after graduation may be less fit to do its work than he was four years earlier. He may have learned to depend on text-books rather than observation, and on authority rather than on evidence."

GLASS-MAKING[1]

By WILLIAM R. STEWART

IN 1827, a carpenter of Sandwich, Massachusetts, wanting a piece of glass of a particular size and shape, conceived the idea that the molten metal could be pressed into any form, much the same as lead might be. Up to that time all glassware had been blown, either offhand or in a mold, and considerable skill was required and the process was slow. The glass manufacturers laughed at the carpenter, but he went ahead and built a press, and now the United States is the greatest pressed-glassware country in the world.

In 1890, a novice in the plate-glass industry, Henry Fleckner, of Pittsburg, whose only knowledge of glass had been acquired in a window-glass factory, invented an annealing "lehr," the most important single improvement ever introduced in plate-glass manufacture. In three hours by the lehr the same work is done which under the old kiln system required three days. In four years, the importations of foreign crown and plate glass into the United States fell in value from two million dollars to two hundred thousand.

About the same year, Philip Argobast, of Pittsburg, also a novice in glass-making, invented a process by which bottles and jars may be made entirely by machinery, the costly blow-over process being avoided, and the expense of bottle-making reduced one-half. The result

[1] From "The Cosmopolitan Magazine." Copyright, 1904, by the International Magazine Company.

has been that more bottles and jars are used in a month now than in twelve months ten years ago.

These revolutions made in three important branches of glass-making by the inventions of men whose practical knowledge of the art was small, have brought about a development of the glass industry which is significant of a new idea in organization. This is a recognition of the importance of experiment in the general scheme of manufacture, and of the value of purely experimental plants as adjuncts to the main enterprise.

The manufacturer who considers only the present is likely soon to have no present to consider. In an age when successful industry needs to have yoked to its wheels not only the best applied science, but also the genius of new ideas, improved methods and far-seeing plans for development, the part of the experimenter is an important one. At least two of the principal glass-manufacturing concerns of the United States now maintain large experimental factories, where tests of new inventions are constantly being made.

The preëminence of the United States in glass-making has been coexistent with the history of the industry here, for the first manufactory erected in America by the English colonists was a glass-works at Jamestown, Virginia, in 1608. In the following year, some of the products formed a part of the first cargo of goods ever exported from this country. The output of this first factory probably consisted exclusively of bottles, with perhaps a few beads for the Indians. But it speedily fell into decay, and it was not until the erection of a large factory at Pittsburg, in 1797, where coal instead of wood was first used for fuel, that glass-making in America began its career as an important national industry. Now Pittsburg is the greatest glass city in the world.

Successive improvements in glass-making machinery, and the use of natural gas for fuel, have not only given a better product at greatly less cost, but also have made possible the carrying out of operations on a scale hitherto undreamed of. In plate and window glass the product is now measured by the square mile where formerly it was reckoned in feet; hollow ware, by the ton instead of in pound lots.

With the more complete organization of the industry, it has become no longer necessary that the great glass-factories should be a gradual evolution from smaller plants. The progress of industrial analysis has reached the point where the most extensive works may spring up at once, fully equipped and with all the requirements of successful operation, wherever the necessary conditions are found.

There are at the present time about four hundred active glass-making establishments in the United States, with a capital of about seventy million dollars. Half a century ago, there were ninety-five establishments, whose combined capital did not reach three and a half millions. Sixty-five million dollars was the value of the glass product of the country last year; four million six hundred thousand the value fifty years ago, when glass cost twice as much.

Large consolidations of interests have been a feature of the glass as of all other industries in recent years. At present two-thirds of the aggregate capitalization of all the glass-making concerns in the United States are divided among five corporations having their central offices located in Pittsburg. Among them they control ninety-two separate plants.

An interesting outcome of the consolidations is disclosed in reports made to the census authorities dealing

with salaried officials and wage-earners. From these it appears that during the ten years from 1890 to 1900, during which the consolidations were effected, the number of salaried officials, clerks and other attachés, employed by the glass companies increased more than one hundred per cent, and their salaries increased also more than one hundred per cent. On the other hand, the number of wage-earners, that is to say laborers, was greater in 1900 by only about seventeen per cent, and the increase in laborers' wages was about thirty per cent.

Not in all the long list of modern industries is there another which affords so many novel scenes as glass-making. Within immense buildings, where the heat in the furnaces sometimes reaches the inconceivable intensity of twelve thousand degrees, and in the draft created by hundreds of huge machine-fans and great openings in the sides of the buildings thousands of employees work busily, with scarcely any clothing above the waist, guiding the great vessels of molten metal, operating the myriad machines, twirling the glowing glass on the ends of blow-pipes and trundling the finished product into the packing and shipping-rooms of the establishment.

Twelve thousand degrees! Sixty times as hot as the temperature of boiling water! It is little wonder that the glass-works are shut down during many weeks every summer and that no glass is made till they reopen in the autumn. The furnaces which are built to withstand this tremendous caloric pressure would put to shame the hottest creations of Nebuchadnezzar the king.

They are constructed of the best fire-brick, especially manufactured, the walls being from two to three feet in thickness, and bound about with great bands of iron, to keep them the more solid. Over the furnace a fire-proof arch is built, and everywhere in the factory fire-proof

materials are used in construction. Only in the packing-rooms are combustible substances allowed.

The basis of all glass is silex, or flint, and an alkali, both of which are opaque bodies which when fused together become translucent. The silex is furnished by sand, whose principal constitutent is silica, the oxide of silicon. Silica, will, when in contact with substances of an opposite character, unite with them, under suitable conditions, such as are furnished by intense heat, and form a salt.

The well-known story of the discovery of glass by Phenician merchants who rested their cooking-pots on blocks of natron and found glass produced by the union under heat of the alkali and the sand of the shore, is consistent as far as it takes account of the chemistry of glass, but scarcely to be believed on the score of the possibilities of sufficient heat from the Phenician's fire.

The alkalis commonly used in the manufacture of glass are the salts of soda or potash and lime, with sometimes the oxide of lead (litharge) taking the place of the lime. Instead of the salts mentioned, barilla, kelp or wood-ash may be used to make inferior grades of glass. Coarse or fine sand is employed, according to the variety of glass required. Glass sand in practically inexhaustible quantities is found in many parts of the United States, but the chief sources of the supply are in Pennsylvania, West Virginia, Illinois, and Missouri.

The ingredients of the several kinds of glass vary, but the substances which form the essential basis of all the varieties are: (1) silica, as the acid element; (2) soda or potash, as the alkaline base, and (3) lime and oxide of lead, as the alkaline earths. As illustrating the different proportions in which the ingredients of glass are mixed in forming the different kinds, the following may be given as the composition of three varieties: Flint glass — sand,

three parts; red-lead, two parts; carbonate of potash, one and one-half parts; a little saltpeter and an oxidizing agent. White window-glass — sand, fifty parts; dry sulphate of soda, twenty-five parts; powdered quicklime, nine parts, and charcoal, two parts. Green bottle-glass — sand, ten parts; kelp, three to four parts; lixiviated wood-ashes, three to four parts; potter's clay, eight to ten parts, and cullet, or broken glass, ten parts.

In the actual making of glass the ingredients are first thoroughly mixed, the mixture, or "batch," then being put into pots — or, as is generally the method now, into one great tank — and placed in the furnace. A continuously high temperature is then necessary to the perfect fusion and amalgamation of the ingredients. Any scum that may rise to the top in the process of making is skimmed off with iron ladles, when the molten glass appears colorless and translucent. The temperature of the furnace is then gradually lowered till the glass becomes of the consistency of a paste, just soft enough to be shaped without risk of cracking. This process of vitrification usually requires from forty-eight to seventy-two hours. Glass is colored when in its molten state by an admixture with metallic oxides. For green or yellow, oxide of iron is used; for purple and black, black oxide of manganese.

The tanks, or pots, in which the glass-mixture — "batch" is the technical term — is melted are made of the best obtainable fire-clay, which is known as pot-clay. Until recently, German clay was thought the best for this purpose, but here again the American manufacturer has been made independent of foreign supply, for large deposits of the clay which excels in quality the German article, have been found in Pennsylvania, Missouri, and some other states. Strangely enough, the only success-

ful method which has as yet been learned for mixing this clay preparatory to making the pots is by constant treading by barefoot workmen.

There is a strange uncanniness about melted glass which forms one of the first impressions that a visitor to the works obtains. The viscous, translucent substance sputters and flows in the pots and molds, squirms like a thing alive impaled on the tips of the blow-pipes, crawls like a dying serpent over the floor, slower and slower, as it cools and hardens.

And everywhere the partially naked workmen, pushing steaming tanks along lines of rails or swinging their pipes with balls of glowing glass at the ends, the mold-boys working the molds or carrying away the product in their snaps, the choked roar of the furnaces, the bubbling of pots and tanks, the hot breath of the unseen fires, give to the glass-factory the semblance and some of the reality of a miniature inferno.

The greatest advance which American glass manufacture has made in recent years is the substitution of the tank for the pot-furnace for melting purposes. In the glass-melting furnace the "batch" to be melted is exposed to the action of the flame, but not to contact with the burning fuel. In the old pot-furnaces, the method was to place a number of melting-pots, each with a capacity for about a ton of metal, immediately inside the furnace wall. The mixed raw material was then filled into them through an opening in the side of the furnace opposite each pot. After the melting process was completed, the glass was gathered from the pots through the same openings. In the tank-furnace, pots are entirely dispensed with, and the glass is melted and held on the hearth of the furnace itself, the flame sweeping across its surface.

The continuous tank is divided into three compartments. Into the first the "batch" is shoveled to be melted. As the "metal" is formed, it runs through a hole at the bottom into the second compartment, where it is refined and passes along to the third, from which it is taken out to be used. By the tank the supply of melted glass thus is maintained continuously, which was not the case with the pots. Everywhere these great tanks are now being installed, supplanting the older appliances.

The use of gas for fuel, instead of coal, is another of the chief improvements of modern glass-making, effecting a saving in cost of fuel of fully fifty per cent, reducing the time required to melt, improving the quality of the glass and lengthening the life of the tank. Gas fuel also has made possible the carrying out of operations on a scale before undreamed of. The discovery a few years ago of large natural gas-wells in Pennsylvania and Ohio gave a tremendous impetus to glass-making in those states, and the "boom" growth of a number of the towns where glass-factories were established forms one of the industrial fairy-tales of the country.

In the method of heating the gas-fired furnace of the glass-works, there is illustrated so strikingly the modern trend to utilize in some manner every waste product, that it is worth mentioning here. In these furnaces air and gas flues rise vertically at either end and terminate in ports at or below the hearth level. The waste gases pass out through a series of thin-walled flues, while the incoming air is admitted through a second series of thin-walled flues, and coming in contact with the first, absorbs the waste heat. Still another method of making waste heat serve a useful purpose is to convey it by a series of flues so as to heat the hot-water system of the entire plant.

There are four general forms which manufactured glass

Blowing Glass

is made to assume, and which divide the industry of glass-making into its special departments. These are flat glass, hollow glass, pressed and massive glass, and colored, opaque and enamel glass. The means by which the melted mixture is given its various forms are: (1) by casting, (2) by blowing, and (3) by pressing in molds, in which latter operation the other two processes may be partly employed.

Under the classification of flat glass come plate, sheet and crown glass, the latter two being the same in composition. It was not until 1879 that plate glass could be manufactured at a profit in the United States. In that year, the domestic production was about seven hundred thousand square feet, and the importations from Europe five million feet. In 1903, the plate-glass consumption of the United States exceeded twenty-two million square feet, of which the imports from Europe amounted to only a million. Not only have American plate-glass manufacturers supplanted foreign makers here, but a considerable industry in exports has already been established. This result has been attained in spite of the fact that the average of wages paid in plate-glass manufacture in the United States is about two hundred per cent higher than in England, and three hundred per cent higher than in Belgium.

Sheet glass, the kind used for windows, is made by an entirely different process from plate glass, and involves two principal operations, blowing and flattening. During the past ten years, a great improvement has been made in the manufacture of this kind of glass in the United States by the introduction of the continuous tank-furnace for melting the crude materials.

About ten million lamp chimneys a year now satisfy the demand for that article in the United States, although

before gas and electric light came so generally into use, ten times that quantity was required. In tumblers, however, which are made by a similar process, the demand is out of all proportion greater than it ever was before. About one hundred million tumblers were made in 1903 in the United States.

In the manufacture of both tumblers and lamp chimneys great mechanical progress has been made in recent years, the machine now supplanting hand-labor in most factories. This machine has a circular table, carrying a series of duplicate molds, which revolves around a central column. The ball of soft glass, gathered on the blowpipe, is put in a mold, which is then closed, the blowpipe being held in place above the mold by a clamping device at the top of the machine. A rubber hose, placed over the mouthpiece of the pipe, leads to a supply of compressed air, which the mechanical rotation of the table admits to the pipe. This latter is kept revolving, and blows up the glass in the mold until it is ready to be turned out for the finishing process. The air pressure is regulated by an ingenious mechanism, and the entire operation is performed with great rapidity.

American manufacturers have long excelled in the making of pressed glass, which includes tableware, lamps, glass ornaments, and the like, the pressed tableware of this country especially having been for years unrivaled in brilliancy and in its close imitation of the more expensive cut glass. This brilliancy is obtained by what is known as the fire-polish finish. In beauty and variety of design pressed tableware has even surpassed the real cut ware. Every year the principal manufacturers offer new designs in the pressed product, which are obtained in great profusion and at large cost.

The molds for pressed glass are made with very exact

surfaces, and when in use are kept a little under a red heat. The various parts of the mold are so made that when closed they leave internally a space representing the form and size of the article to be made, the internal hollow in the article not being produced by blowing but by the plunger of the press under which the mold is placed.

Glass with elaborate facets, flutings, or other ornaments, can be made with great rapidity in these molds, by means of the plunger which presses the soft metal into every part of the cavity. The fire-polishing, which gives brilliancy to the pressed glass, is accomplished by reheating the article sufficiently to melt a thin superficial stratum. This removes the roughness and obscurity of surface incidental to molding.

Almost twenty million dollars' worth of raw material was required for the glass manufactured in the United States in 1903 — more than forty per cent more than was needed ten years previous to that date. These materials consist of glass sand, soda ash, salt-cake, litharge, fuel, packing materials, nitrate of soda, potash, fire-clay, and the like.

The preparation of sand for the glass-factories has become a highly specialized business, fully a score of separate establishments being exclusively engaged in the industry. The supply of soda-ash for glass-making a few years ago was almost entirely from England, but at the present time the domestic production is equal to the demand. The salt-cake used also is now all made in this country, while a decade ago it was mostly imported. A considerable quantity of litharge is imported from England, but more and more of the material is being produced in the United States.

CASTING A GREAT LENS[1]

By RAY STANNARD BAKER

IT had just turned afternoon in the furnace house of the glass works of Jena. For upward of two hours everything had been in readiness for the casting of the great lens, everything except the glass. The Master had directed the placing of the huge circular iron mold near the open doorway and just between the two furnaces — the one from which now burst the fervid white radiance of the molten glass, and the one in which through weeks of lessening heat the lens, when cast, was to be cooled and toughened and tempered. The mold was a meter and a quarter in diameter, — over four feet, — and the lens here to be cast would make one of the largest in the world, large enough to bring the moon within a few score of miles of the earth, and one so perfect, perhaps, as to surprise new secrets from the sun itself.

The Master had sprinkled the bottom of the mold with fine sand from a curious tin pot, that the hot glass might not take up impurities from the iron. A dozen brawny workmen, in blue blouses and wooden-soled shoes, had come in to man the long, wheel-mounted tongs which were to drag the crucible from the furnace bed. Other workmen with sledges and bars had torn a gaping hole in the front of the cooling furnace, so that it would be ready for the instant admission of the lens.

So everything was ready. The Master, shading his

[1] By permission of the Author and "McClure's Magazine." Copyright, 1900.

face with his upraised arm, peered into the "glory" hole of the melting furnace, as he had been doing with ever greater frequency for hours past. He watched for a moment the shimmering, wrinkled surface of the molten glass within the crucible, and then he followed the movements of the stirring lever. Was the color exactly right? Did the sluggish waves which followed the stirring plunger show thick or thin enough?

At last the time came. The Master gave the word, and a dozen men sprang forward with hooks and bars. The "glory" hole was hardly larger than a man's head — just sufficient for the passage of the stirring lever and to permit examination. With this as a beginning, the workmen tore out the whole front of the furnace, working with the utmost activity, their heelless shoes clattering on the stone floor as they rushed back and forth. The stirring lever was dismantled, and the stirring plunger itself, white-hot and sparkling with the dust that fell upon it, was cast outside, where it lay, a deep wine-red, in the sunshine.

The grappling tongs were thick bars of steel about thirty feet long, mounted on iron wheels. As soon as the furnace was open, the grappling ends were thrust inside, one on each side of the crucible, the men at the other end leaning back with heads averted to avoid the fervid outburst of heat.

Although the novice could not see it because of the brightness of the glow, there was a thick ridge around the crucible, about halfway up. Under this the tongs fitted themselves. The men at the other end bore down hard, but the crucible did not stir. It was firmly fastened to the furnace floor by the glass that had spilled in the melting. It was an anxious moment. Crucibles have been broken in lifting. The Master raised his hand. Slowly the men added their weight at the far end of the lever.

The crucible broke suddenly free, jogging a little, so that a bit of the glass overflowed and ran down like thick syrup. An instant later the crucible was outside the furnace, filling the whole of the high dim room with heat and light, like a new sun. And thus it was pushed down the room toward the mold, a thing of exquisite beauty, and yet of terror, showing a hundred evanescent colors, changing red, pink, yellow, violet.

The crucible was lowered to the floor, the tongs were removed, and a workman cast a beard of asbestos over the glass to prevent too rapid cooling. Here it stood a few minutes, and when the crucible began to define itself, one discovered that it was made of fine yellow glazed pottery. Imperfections on its surface stood out like specks on a mirror, or as one would imagine the spots on the sun.

It had required long hours for a man to fashion the clay of this crucible, and many weeks for it to dry, and then for days before it was used it had been slowly heated to prepare it for the high temperature of the furnace. And with this single melting its service is finished and it is consigned to the scrap heap.

Three men with thickly gloved hands are now fastening an iron band around the crucible just under the ridge. On each side of this band there is a protruding pivot of steel which fits into a socket in the ends of the grappling tongs, thus permitting the crucible to be tipped up as if on an axle. Again the men rest their weight on the other end of the tongs, the crucible is lifted, and an instant later it is poised over the iron mold. The critical point of all this labor has at last been reached.

There is a pause, as if the workmen felt the anxiety of the moment. The foreman, with his hand ready on the tilting lever, awaits the Master's word. There is a shout, a quick upward swing of the foreman's arm, and out from the

crucible slips the molten glass. It has been a moment of so much stress that one anticipates a crash as the glass touches the cool iron of the mold, but there is absolute silence — not so much as a hiss or the sound of the splash. There is something indescribable about the fluidity of this mass. It seems thick, like oil, and yet it spreads more swiftly than water: it is more like quicksilver than anything else that one can think of, and yet not at all like quicksilver.

The mold, with the glowing lens inside, was now covered with a plate of iron, wheeled to the mouth of the cooling furnace, and lifted with chain tackle to the height of the furnace floor. A movable-frame tramway was then placed underneath it, and it was quickly pushed into the furnace. Workmen were ready with brick and mortar, and in ten minutes the lens was walled in. Here it is cooled for two weeks, and then brought again to the open air, dull and milky of surface, and possessing only the general shape of a lens.

After that, for days and weeks, workmen are employed in polishing it, not to give it the final form which it will have in the great telescope, but merely to prepare it for that important and anxious day when it will be submitted to those searching tests for imperfections, during which it must pass even the close scrutiny of microscopic and spectroscopic examination. A few bubbles it may have and pass, for bubbles have no effect, except to reduce the passage of light in a minute degree; but veins, denoting the improper mixture of the ingredients of the glass, it must not have. If it passes all the tests — and sometimes it requires many castings and costs many rejected lenses of this most precious of glass before the necessary perfection is attained — it is again sent to the furnace house, where with even greater care than before it is slowly raised

to a high temperature, and thus annealed, and then as slowly cooled for two months or more.

After that it is ready for the lens-maker proper, that skilled mechanician and mathematician of Jena or of America or of France, who polishes down its sides with infinite care, until they reach the most perfect curves appropriate to the refraction and dispersion of the glass disks employed. Each of these processes has absorbed precious time and has cost much money: the bare glass for such a lens would cost about five thousand dollars. To this the skill of the optician would add in polishing perhaps twenty thousand dollars more, so that the finished lens, ready for fitting into the telescope tube, would represent an expenditure of some twenty-five thousand dollars. Through such pains and expense as this must science pass that mankind may add a few facts to its knowledge of some distant star.

THE AGE OF PAPER[1]

By CHARLES H. COCHRANE

THE age of electricity and the age of steel are frequently referred to in the daily newspapers and magazines, but it certainly appears as if the paper industry was quite as much entitled to that sort of distinction. Without paper we should be without printing, and without printing there would have been no development of either electrical machinery or steel construction, or of the knowledge that has enabled men to develop these great industries. All paper was hand-made until about 1800, when the Fourdrinier brothers invented the paper-making machine, this being one of the few instances where a machine has reached its full development from the hands of the first inventors and builders. While the paper-making machines of to-day are very much larger and more complete than the first ones built by the Fourdriniers, yet they are the same in essential principles, having the same leading characteristics.

But for the paper-making machine turning out paper in the roll, fast rotary printing-presses would be impractical and the progress of printing would have been much delayed. There is no more common article of manufacture than paper, and there is scarcely a trade or business that is not very much dependent upon its use. Without cheap paper half of the business of the country would be paralyzed. Because paper is so cheaply produced and

[1] From "Modern Industrial Progress." Copyright, 1904, by J. B. Lippincott Company.

so easily obtained we seldom think of its value in all lines of industry.

In 1794 the first paper-mill of the United States was started in Troy, New York, having a capacity of five to ten reams a day of rag pulp. Several other paper-mills were started during the following years, manufacturing rag pulp by hand until 1817, when the first steam-mill was started at Pittsburg. By 1842 there were some fifty thousand persons employed in the paper-mill industry in the country, producing paper annually of the value of fifteen million dollars.

Pulp-straw made its appearance in 1857, being manufactured at Fort Edward, New York. By the time the Civil War broke out newspapers were using this straw-paper very largely, the price of rye straw increasing from six to twenty dollars a ton. Poor and brittle as this paper was, and hard on printers' type, yet the newspapers were glad to get it at from twelve to twenty-six cents a pound during the war. Newspaper circulations were largely stimulated by the political excitement culminating in 1861, and, as a result, the product of our paper-mills began to exceed that of Great Britain and France. A boom in paper-making came with the introduction of wood-paper, about 1870–75. At first, wood-paper was regarded as a cheap article comparable with straw-paper; but, as its merits were better understood, and as the makers learned improved ways of strengthening and finishing, its popularity began to grow, and to-day ninety-nine one-hundredths of the world's paper made is of wood, fine papers designed for the higher grade of artistic printing being manufactured from wood-pulp and depending upon sizing and calendering for their beauty.

Cellulose is the chemist's term for the substance obtained by pulping wood, as in the manufacture of paper.

Wood-pulp is the common term used in the paper trade, meaning what its form implies — wood that has been reduced to a pulp. Most of the wood used in the manufacture of American papers grows in the forests of Canada and the northern borders of the United States.

The hardy lumbermen chop down the trees and lop off the branches, leaving the trunks to lie until the logging season sets in. The transportation of the logs to market involves great ingenuity because of their size and weight, and the fact that they are obtained in regions where there are no good roads or ordinary methods of transportation.

Advantage is taken of the natural slopes toward the streams to form chutes, down which the logs readily descend during wet or icy weather by force of gravity. Very rude railways are also employed at times or any special device that the locality and ingenuity of the man in charge can suggest. When the logs reach the streams during the cold weather, they must lie there until the ice breaks up, when the lumbermen prepare to go on the "drive."

The dangers of logging seem to give it an added charm in the eyes of the lumbermen, who acquire astonishing skill in balancing, and appear as much at home on a stream full of logs as a dancing-master is on a ball-room floor. These hardy men keep their logs in motion until they reach a large sheet of water, where they can be tied in rafts and floated to the mills. If the logs have been cut in a maritime province of Canada, they have a sea-voyage before reaching the paper-mill, or, if in the lake region, a similar trip across the waters of one of the great lakes is required to bring them to their destination. For such voyages the logs are made up in great rafts for towing. The sea or lake voyage is uneventful enough in fine weather, but a storm is likely to break up the raft

and scatter the logs for miles, with no little danger to the sailing craft in the vicinity, as a collision with a big log is damaging to the side of any vessel.

Paper-mills are invariably located in the vicinity of water, as near some large water-fall as practicable. The water-fall is necessary for procuring cheap motive power, as well as a plentiful supply of water, which is essential to the manufacture of paper. When the log reaches the mill it is first dragged out of the water by iron dogs and rolled and slid to a great circular saw that cuts it into lengths. At the same time, a "barker," made of rapidly rotating blades, removes the bark from the log with the most tremendous noise. The buzz-saw is supposed to emit one of the worst noises that ever afflicted human ears, but the barker can outscreech three large buzz-saws, and when several saws and barkers are operating together the noise is so deafening as to be beyond the writer's powers of description.

The short lengths of logs when bared of bark are ready for the grinders. In these the wood is pressed hard against a grindstone under a constant flow of water.

The ground pulp so made is called "filler," which constitutes about seventy-five per cent of the material used in paper-making. The grinding of the wood tends to destroy the fiber, and for that reason, in manufacturing the better grades of wood-paper, a chemical process is employed, commonly known as the sulphite process. For this the logs are reduced to chips by a machine having rotating knives, and called the chipper. This reduces the log at a rapid rate, and the stream of chips is transported by an endless carrier to the sulphite-mill to be digested. The digester is an enormous steel tank or boiler, lined with tile, or the like, to prevent the acid from eating into the steel sides. Some of these digesters are

large enough to hold forty cords of chips at a single loading. Into the top the chips are dumped, after which the top is closed and the steam turned on, and the whole cooked at a temperature of perhaps four hundred degrees Fahrenheit for about eight or ten hours. The digested material is taken out through a manhole at the bottom of the digester, and strained to remove any coarse particles of foreign matter, then pressed to exclude surplus water, after which it is ready for the paper-mill. The material obtained by this sulphite process being made from the chips retains longer fibers when reduced to pulp than does that which is ground, and this fiber entering into the finished article, gives added strength to the paper.

Next, the pulp is pumped up to the "wet end" of the machine. Paper-makers call one end of the long paper-making machine the "wet-end" and the other the "dry end." First, at the "wet-end" is the screen, a box-like arrangement where the pulp is screened of all slivers and particles too large to knit into the paper fiber. From the screen it flows into the head box, which is a contrivance that automatically governs the head or flow of pulp upon the machine. This flow has to be nicely adjusted. The flow must be just right for the sheet of paper to be of the right thickness. From the head box the pulp flows out with the wood fiber held in such thin solution that it looks like very thin milk.

The standard width of the wet machine is seventy-two inches face of press-rolls. The cylinder vat into which the stock is received is substantially made of lumber. It supports the cylinder-mold on which the sheet is formed, and has partitions for directing the flow of stock evenly and uniformly over the face of the mold.

The cylinder-mold is a roll built of bronze spiders mounted on a steel shaft, and covered with brass rods

running longitudinally, secured by a close winding of hard copper wire. Outside of the wire winding are two faces of brass wire cloth, fine enough so that the pulp cannot pass through them, though the water readily can.

The couch-roll at the top of the vat may be either rubber or wood covered. From the couch-roll the endless felt carrying the newly formed wet sheets of pulp passes first over the suction-box, then over the guide-roll, and between the press-rolls. The pulp adheres to the upper press-roll, where it is allowed to accumulate to a sufficient thickness and is then cut off.

After depositing its burden of pulp, the felt is beaten by the felt-beater, sprayed by the shower-pipe, squeezed by the squeeze-rolls and stretched by the stretchers, and freed from all adhering particles of pulp, partially dried, and, guided straight in its return course, it passes again to the couch-roll.

In another form of machine the pulp flows on to an endless wire straining-cloth that permits the running off of a large portion of the water. This cloth is guarded on the sides by endless bands of deckles that run under the dandy-rolls of the machine. These rolls carry the wire-cloth, and any particular pattern of wire will produce a corresponding water-mark. The arrangement of the wires at the dandy-roll also serves to determine whether the paper is of the character technically known as "laid" or "wove." While the film of pulp is traveling to the apron it is subjected to a side-shaking, in order to cause the fibers of the pulp to cross each other.

After passing the dandy-roll, a save-all box catches and preserves the water that drains off, in order to save any size or coloring-matter that it contains. The film of pulp passes on to the couch-rolls, and thence to an endless wet felt apron, on which it rests while carried between

a pair of rolls, by which it is transferred to the press-felt apron, and passes to the pressure-rolls. These rolls press out nearly all the remaining water and bring the pulp film almost to the condition of paper. From this point, the paper, as it may now be called, is able to carry itself without a blanket support, and is directed on between various drying and calendering rolls, some of which are heated in order to take out any remaining dampness from the paper. As it emerges from the machine, the paper is wound up in enormous rolls, often a mile or more in length.

About twenty million pounds of paper a day are manufactured in the United States, this being greater than the total output of the mills in all other parts of the world. A little more than a quarter of this goes into the newspapers of the country, a little more than one-eighth into books and magazines, and about one-twentieth part into writing-papers. The remainder is made into wrapping-papers and paper-boards, as for boxes and similar purposes.

In 1891 the Philadelphia "Record" made a test as to the speed with which a tree in the forest could be converted into a newspaper ready for sale. The concern owned a paper-mill, and so was able to carry out the experiment satisfactorily. The time from the putting of the ax to the tree to the offering of the newspapers on the street was twenty-two hours. This record has been surpassed since in Germany, presumably in a place where the mill and printing-press were in the same establishment or close by.

There are several Sunday newspapers in the United States that consume as much as a hundred tons of paper in printing a single issue, thus consuming about one hundred and twenty-five cords of wood and clearing off about six acres of well-grown spruce timber land.

Japanese paper is a distinctly different product from American-made paper. It has a strength of fiber unknown here, and is superior in many ways, as well as much more costly, being hand-made. They use the bark of plants, as the kodzu, cutting it into strips of perhaps a yard in length, which are tied up in bundles, and then softened in water containing a weak solution of lye. The next process is treatment with a special form of mallet for separating the strips into fine fibers, and this is done with a care that secures a much longer fiber than is had in American manufacture. In making the paper, they use, instead of the animal glue, which has such a rank odor, a cement made from the roots of a native plant. The pulped fibers are spread on a sieve to level out the mass by shaking and let the water drain off, much as we do in making paper by hand, after which it is rubbed on a board with a soft instrument, and dried in the sun, when it peels off the board as a sheet of remarkably tough paper. This sort of paper the Japanese use for window-glass, and it is also twisted into threads of great strength that are used in embroidery and ornamentation. This paper is also specially adapted by its porous quality to use for writing on with India ink and a brush, and also for native painting.

The methods employed for testing paper, in order to judge accurately of its quality and value, are both mechanical and chemical. For determining the thickness and consequent weight per ream, a micrometer-gauge is applied to a number of samples, which are weighed, and the calculation usually reduced to the weight per square foot. For determining the strength of paper, a dynamometer is employed that records the weight at which a strip of paper breaks under strain, and also the amount of elongation before rupture. In making this test, strips

Paper Making

are cut from the paper, both in the direction of the fibers and across the grain. The latter strip of paper is the weakest. Tests for friction are usually made by hand, folding and unfolding the paper, and noting how many times it can be creased before breaking, and also by alternately crumbling the paper and smoothing it out.

In order to judge of the sort of fiber used in a paper, it is cut into strips and boiled in a one per cent caustic solution. When it is sufficiently pulped it is collected on a wire gauze and examined under the microscope. If the fibers appear brown they are either cotton, hemp, flax, or ramie; if yellow, jute; if no color is apparent, it is either wood- or straw-pulp or alfa. Straw is detected by the oblong cells in the fiber showing under the microscope, while alfa exhibits very fine fiber and saw-teeth, cotton resembles a ribbon with swellings and spirals, and wood has transparent wide and flat cells.

As most paper is made of wood-pulp, and its quality is usually improved by the addition of stronger fibers, it is often desired to determine the amount of wood-pulp in a given paper. This is done by dipping a sample of the paper into a mixture of hydrochloric acid and phloroglucine dissolved in alcohol, when the wood-pulp reveals a rose color — the rosier the tint the greater the quantity of wood. There are sometimes free acids in paper, which are damaging to its quality, and these may be detected by burning the paper and analyzing the ashes.

STORY OF THE MILLING INDUSTRY[1]

BY S. B. WASHBURN

THE grinding or crushing of the wheat berry, in order to make it fit for baking, is one of the oldest of industries. Modern flour milling, on the other hand, is a development of the last thirty-five years.

Hollowed rocks and other primitive grinding tools are found in the dwellings of the prehistoric stone age, and are still used by savages and semi-civilized peoples in various parts of the world. It has taken countless centuries to progress from them to the consecutive rollers of the present-day process, which makes possible the turning of hard spring wheat into a straight or standard patent white bread flour, rich in gluten, and including much that in the old process of milling was lost in middlings and bran.

A kernel of wheat consists of three distinct parts:

1. At one end the tiny germ, which develops into a plant.

2. The vastly larger portion, comprising eighty-six per cent of the whole, which nature designs as food for the young plant during germination, and which is the only part that enters into our fine white flours.

3. The protective coverings, in several layers, called "bran," making up nine per cent of the kernel.

Under the process of milling in use until after the close of the last century, the wheat berry was ground in a set of stones with cut faces run not quite touching each other; and the fine flour was obtained by sifting the product

[1] By permission of "The Technical World."

through sieves of varying fineness. As close grinding would reduce some of the hard outer coats of the berry to fine powder, thus making a dark flour, it was necessary, in making fine white flour, to use only the softest wheat, which would crush readily, without powdering the dark outer coats. Such wheat is starchy and contains relatively little protein. The use of this flour made Liebig recommend a return to whole-wheat flour, and gave the so-called "Graham" flour its great vogue.

The introduction of the roller process of milling from Hungary made it possible to use the hard spring wheat berry in the making of fine white flour. This berry is much richer in gluten than the softer variety; and the result is that standard white flours of the present day, made from hard wheat, carry more protein than almost any Graham flour on the market twenty-five years ago, and as much as or more than many such flours now in use.

As in so many other great industries, the United States stands first among the countries of the world in flour milling. The world's production of wheat for the year 1903 was three billion two hundred million bushels. Of this total, the United States furnished six hundred and forty million bushels, which is the equivalent of one hundred and four million barrels of flour, an allowance of more than one barrel per year per capita of population. Less than eighteen million barrels was exported.

There are in the United States twenty-five thousand flour mills employing a total of forty thousand workmen, who earn a yearly wage of seventeen million dollars. First among the states as a flour producer stands Minnesota. This state has but five hundred flour mills; but they are so far the largest of their kind that they produce more than one-fifth of all the flour ground in the United States.

Minneapolis is preëminently the "Flour City," though

another — Rochester, New York — earlier acquired the name. On either side of the Mississippi stand the great stone mills, the wheels of which are turned by power taken from St. Anthony's Falls. Five of these Minneapolis mills alone have turned out almost ten million barrels of flour in a year. The process of milling in all great modern plants is essentially the same.

All over the hard wheat belt of the Northwest, and far up into the Red River valley of the North, stand giant elevators, into which the wheat is gathered from the surrounding farms. To a considerable extent these elevators are owned and controlled by the large flour-milling corporations. From them it is conveyed directly to the mills.

How great is the consumption of wheat may be gathered from the fact that the mills of a single Minneapolis corporation grind three hundred carloads every working day in the year.

At the mills the wheat is received in a large hopper, and weighed. It is then elevated by an endless chain of cups to the bins at the top of the building. From the bins it is conveyed to the "cleaning house," where it passes through a series of ingeniously contrived separators, which extract the cockle, stub straw, mustard-seed, oats, and the like. The grain then goes on to the "scourers," where the fuzz and dirt are removed by attrition. The refuse is sold for chicken feed. Leaving the scourers, the wheat passes through a cast-iron box containing countless revolving brushes, which dust the kernels as they drop through on their way to the subterranean storage bins below.

When the milling process proper begins, endless conveyors again take the wheat to the top of the mills, whence it starts on its downward journey through the many intricate machines situated on the different floors. The first of these crushes the kernels between chilled iron rolls —

the preliminary step in the gradual reduction process. These machines are small and compact, and consist of grooved rollers revolving at unequal rates of speed, thus securing the effects of both crushing and cutting.

This is the process which was imported from Hungary, and which revolutionized the flour industry. During the first reduction, the grain passes through six of these machines, the product from each one being conveyed to and through the separating reels, which consist of long, cylindrical boxes covered with bolting cloth. Here the "middlings" or "grits" are separated, the residue being sent to another set of rollers, in which it is crushed more finely, then back to a finer sieve, this being repeated six times. As the rolls in each successive break are closer together and the sieves smaller, the middlings are naturally finer after each operation, thus causing six different grades in size and quality.

The middlings are then passed through the "middling purifier," the machine which permitted the use of spring wheat, and which might be termed the revolutionizer of the flour industry. This machine consists of a large box containing sloping frames covered with silk cloth and shaken by an eccentric. Underneath are brushers which work back and forth, thus preventing the meshes from being clogged by the flour passing through, a current of air at the same time taking up the fine bran and dust into a series of flannel tubes. This purifier was invented by one Joseph Perrigault, a Frenchman.

From the middling separators, the dust is shaken into a conveyor which takes it to a bolting reel, where a low-grade flour is obtained. The middlings themselves are not yet ready for the final reduction into flour, as they are of an oily nature and a yellow color. To eliminate these defects, they are passed through a series of smooth iron or

porcelain rolls, which flattens the germs sufficiently to be sifted out by bolting reels, the extracted germs being mixed with bran to make feed for animals, while the now purified middlings are ready for the final grinding into flour. They are raised to the top floor and deposited in bins, each bin being designated for special grades.

When wanted, the flour to be is allowed to drop through chutes into the desired machines, one to seven additional reduction processes being necessary before the final grinding between stone wheels. At the end of this operation it is again deposited in bins, on the second floor, ready to be placed in sacks and barrels. This work is performed on the next lower floor, sheet-iron tubes connecting the flour bins with the barrels or sacks.

Thus, from the moment the cars of wheat are unloaded by automatic grain shovels, the wheat, middlings and, finally, the flour are elevated and conveyed in all directions from, to, and through one machine and another, and the finished product put into the proper sacks and barrels, without the direct intervention of man, the work being performed by most ingenious automatic machinery.

But to the modern miller even this is not sufficient. Samples of the flour are sent every hour to the experimental and testing departments, where a portion of it is placed in a glass bottle and is numbered to correspond with the number of the milling which is marked on the barrel or sack. The other portion is carefully weighed and made into bread, mixed and baked scientifically, the degree of heat of the oven being exactly ascertained. The baked loaves are then weighed and measured, and the texture of the grain examined, the results being marked upon the bottles containing the milling. These are saved for several years, thus permitting a test or examination at any time that such may be required.

MODERN STEREOTYPY[1]

By HENRY A. WISE WOOD

PRINTING began with the making of hand-cut blocks, which were used to stamp their similitude upon other surfaces. Later, blocks called type, bearing each a single character, were made, and these, when combined one with another, produced words which, when gathered into sentences and paragraphs, became the page. The great impetus given the typographic art by the introduction of "movable types" was due to the ease and economy with which text could be prepared for the press, and after printing, the type page resolved again into its component characters, which thereupon were fit and ready for further use.

The work of cutting characters being slow and costly, recourse was soon had to casting them of an alloy of lead, antimony, and tin from molds, now called matrices. These were made of plaster from types or dies which had been cut by hand; and later of copper from harder dies which, upon being driven into it, left their impress. Until recently the driven matrix was exclusively used; but nowadays the manufacturers of type cut their matrices by means of a power-driven engraving device, the controlling lever of which is guided by hand along the edges of a large template, or raised representation of the particular character to be cut.

Thus, by means of the Benton-Waldo machine, unskilled men, working with great rapidity, can produce the most intricate matrices at little cost. When matrices are re-

[1] Courtesy of "Scientific American." Copyright, 1910.

quired to be made in large quantities, as for use with the type-making and composing machines of the modern printing office, they are still driven, the dies, or "punches," employed being engraved by the Benton-Waldo method. The matrices of extremely large type-sizes which are now upon the market, are usually neither punched nor cut, but are electrolytically-deposited copper impressions of existing types.

For many centuries the setting of type was a manual operation. It required a high degree of special knowledge and great dexterity. With the setting, or "composition," of a page the type-setter's work did not end; when the page was no longer required he had also to "distribute" the type it contained. The putting of matter into type involved the necessity of taking it out again.

Such a dual process was entirely comfortable to the printer until, and long after, the newspaper came into being. But when the value of celerity in the printing of news began to be understood, the slowness of "the man at the case," became irksome, and a mechanical substitute for his eyes and hands was sought. This brought into being the crude type-setting devices of the third quarter of the last century. These, like the man, had to distribute as well as to compose, and each function was given a mechanism of its own.

Meanwhile the growth of the newspaper in telegraphic matter and general build was pushing it on to demand still more rapid and ample appliances; and these, as far as the composing room was concerned, were at last supplied by Mergenthaler's matrix-setting and type-line casting machine, called the Linotype (line of type). This device worked upon a new principle. Instead of seeking to set the types, and after their use to distribute them among their respective receptacles, in order that they might again

be automatically composed, it composed the matrices of type, and from these cast, as a single piece, a line of characters.

By the mere acts of playing his keys and touching a handle upon the assemblage of a line of matrices, an operator was enabled to make composed and justified lines of new type at a then unheard-of rate of speed. Moreover, the "type" he had set needed not to be distributed for re-use; the line had only to be tossed into the melting pot of the machine to be born again as new matter. Where other mechanical compositors had required three men for their use, one to set, another to justify, and a third to distribute their work, the Linotype needed but one, and could be worked with such ease and rapidity that it went instantly into general use.

Upon the heels of the success of the Linotype came another device, the Monotype, which, although not of so great value to the newspaper publisher, was gladly received by the printer of books and commercial work.

Coincident with the introduction of movable types one first hears of the printing press. This instrument is said to have come of humble origin; to have been, in fact, but a development of the cheese or cider press common in mediæval times. It consisted first of two plates between which the inked type, covered with a sheet of paper, was introduced and by which it was pressed. The necessary squeeze was applied by means of a hand-turned screw, set in a surrounding frame, which bore upon the upper plate. Next came an improved form of screw-operating mechanism. Next, the lower plate was made to slide out to receive the type "form," as it is now called. And later a frame, covered with fabric to which the sheet was secured, was made to hinge down upon the type before the table upon which the type rested should be slid beneath the

upper plate. This table is now called the "bed," and the sheet-pressing plate the "platen," of a press.

In those days the ink was applied by means of hair-stuffed leathern balls. These, dabbed with ink, were patted together until their ink film was suitably evened out or "distributed," and were then carefully pressed upon the type. With such a press about two hundred sheets of small size, printed upon but one side, should be done in an hour. At its next step the press became of iron, and was adapted to print larger sheets.

Then a genius conceived the idea of replacing the flat, sheet-pressing platen, by a rotating cylinder upon the surface of which the sheet was held by bands of tape. Beneath this cylinder the type form was pushed, and thus the cylinder printing press was born. Next were applied ink-charged rollers made of glue and molasses which, as the type was pushed toward the cylinder, served to ink it. Better means for propelling the type-bearing table or bed were soon forthcoming, as well as for causing the cylinder to turn more accurately, and with greater certainty to take on and give off the sheet. Power other than that of the hand was applied, and it became possible to print upon one side of a sheet at the rate of a thousand "impressions" an hour.

Meanwhile the flat or "platen press," as it is called, shared in the general advancement of the engineering arts. It became a self-acting machine; of itself took its sheet from the hand of the printer and drew it into position to be printed, and impressed it upon the type, which it had previously inked. Thereafter it gently laid the sheet upon a table, a thousand such sheets to the hour. Having attained to this degree of development the growth of the platen species of printing press ceased forthwith and, except in connection with the smaller sizes of commercial

work and a few obscure branches of the printing industry, it is no longer a factor.

As an increasing speed of production is ever of the essence of industrial progress, the mechanical species which survive are necessarily those which lend themselves to celerity. Of such a species was the cylinder printing press. With the betterment of materials and of motion-producing mechanisms, the attainable speed of its reciprocating type bed and its sheet-bearing cylinder soon enabled it to out-run the older and more cumbrous flat press; and thus it came to assume the burdens of news printing. The single-cylinder press, printing upon one side of a sheet, was soon followed by a machine having two sheet-bearing cylinders, and a double length bed upon which forms of type for printing the back as well as the front of a sheet were borne. By an ingenious arrangement of endless tapes the sheet, having been printed upon one side by one cylinder, was transferred to another cylinder and by it printed upon its other side. Such a press was said to "perfect" the sheet, and so came to assume the name of "sheet perfecter." Other double-cylindered presses, also, were used, which were adapted to print upon but one side of the sheet. Such a machine carried upon its bed a single form of type to which each cylinder in turn presented a sheet; the one cylinder upon the forward stroke and the other upon the backward stroke of the bed.

Fifteen hundred papers an hour were not, however, long going to satisfy a public rapidly growing in its appetite for news; so another step was taken, this time by Applegath, for the London "Times." By setting a cylinder upon its end, its axis in vertical position, and fastening into it the metal column rules of the paper, Applegath was enabled to lay the columns of type between these rules and so clamp them to the column-wide facets of his cylinder as to

cause the type to withstand the centrifugal force of a quite respectable velocity of rotation. About this type-bearing cylinder were set parallel sheet-bearing cylinders, to and from which hand-fed sheets were conveyed by rather complicated systems of tapes. In this way the "Times" for many years was printed. Hoe in this country conceived a better arrangement. By the use of wedge-shaped column rules he was enabled so firmly to hold the columns of type in place as to enable him to set his cylinders in a horizontal position. Hoe presses having four, six, eight, and even ten sheet-bearing cylinders, which ran in contact with a central type-bearing cylinder, came into general use. Having a "speed" of two thousand turns of the type cylinder an hour, such a press, with ten sheet-bearing cylinders, was capable of turning off twenty thousand sheets. These being printed upon but one side, had of course to be put through the press again, the type pages meanwhile having been changed. Hoe's next step was to place in a machine two type-bearing cylinders so that both sides of a news sheet might be printed at a single operation.

But even ten or twenty thousand newspapers an hour failed to satisfy the growing public need. The presses of the day were already working at top speed. Type-setting was so slow and costly that forms could not be set for more than one press; so an establishment was limited to the use of a single machine. Something had to be done.

For some time there had been known and used the process of stereotyping, which was that of producing replicas of a form of type, in type metal. To practise stereotyping, a type form was stamped into a moist clay surface, where it left its impression. The clay was baked, then put into a receptacle and type metal poured upon it. When the cast had cooled, the clay was broken from its surface, its edges were trimmed with a tool, and its back smoothed

with a plane. Then it was ready for press. By repeating the processes of molding and casting it was possible to continue indefinitely to reproduce a type form. But the resulting stereotypes were flat, and for the rotary news press it was desirable, if higher speed were to be obtained, that printing forms should conform to the curve of its cylinder.

In this hour of the newspaper's need someone, it is not certain who, conceived the idea of substituting for the clay for stereotyping a sheet of papier maché. This was composed of several thicknesses of soft paper moistened with paste and covered with a skin of tissue. It was laid upon the type and beaten in with a brush. Type and paper were then covered with a dry blanket of felt and thrust into an oven-like press till the matrix was dry. Such a matrix, being flexible, could be conformed to the interior of a curved casting receptacle and, being tough, could be stripped from a cast and used again. This method of stereotyping originated abroad, and was brought to this country by Traske, who first put it to work upon the New York "Herald" and the New York "Sun." Thus, for the first time, the newspaper was enabled to make innumerable curved replicas of its type forms, and indefinitely to multiply the number of its printing machines. It should be noted in passing that with the advent of the curved stereotyped printing plate the larger newpapers ceased for good to use type for the purpose of printing.

Further improvements now followed one another in rapid succession.

In the year 1890 I first became interested in the art of Stereotypy, which was then being practised exclusively by manual means. But a few devices, power-driven and hand-controlled, had been provided to facilitate its work. One was used to remove the riser or sprue of the freshly

cast plate, while another, when the plate had been dropped into it by hand, served to smooth out the plate's inner, or seating, surface. In but one other function was the work of the hand assisted by power. The moist papier-maché sheet, or "flong," as it is called, after it had been laid upon the type-page and covered with a felt pad, was molded to the face of the latter by an iron roller beneath which it was drawn upon a bed propelled by power. Excepting these, all of the operations of stereotyping required the direct employment of the thought, the eyes, and the hands of workmen.

The process of stereotyping then in vogue may briefly be described as follows: To prepare the flong, two blotter-like sheets of paper were pasted together, and upon one side of these four sheets of close-fibered rice-straw tissue were pasted. The paste used, its composition then a trade secret, was of flour, a clay, and a germicide, the latter to prevent fermentation. Flongs enough were made for the next day's requirements, and these were allowed to season in a moist place. As each type-page reached the foundry a flong was laid upon it, tissue-side down, and upon the flong a closely-woven stout felt blanket. Page, flong and blanket were then run beneath an iron roller, the operation of molding thus being performed.

Before the advent of the molding-press, the flong was beaten into the face of the type-page by long-handled brushes; a slow process, which the roller superseded. From the molding press the type-page with its molded flong (now become a matrix) still clinging to its face, was carried to a steam-heated iron table, where, the molding blanket having been exchanged for several layers of dry soft blanketing, an unheated iron plate, or "platen," was screwed down upon it. Heat, thus applied to the type, drove all moisture from the matrix into the blankets, and usually in

from four to six minutes the matrix, or "mat," as it is usually called, became dry and was ready to be cast from.

In the eighteen years that have since elapsed this process of molding and drying has undergone but a slight improvement. Better paper and paste have increased the durability of the matrix, and an improvement in technic has made it more sensitive to the delicate "effects" of modern illustrations; but, if a slight reduction of the time consumed in its making be excepted, the process of matrix-making has scored no substantial gain. Of progress in the making of plates, however, a different story is to be told.

When stereotyping was first adapted to newspaper printing, certain implements were necessary in order that suitable printing plates might be made. The employment of the rotary press required that the plates be curved. It was also requisite that they be of uniform thickness, and that their curved ends be beveled so that they might be held by clamps to the cylinders of the press. These conditions necessitated the use of a curved casting-mold, or "box," as it is called. In this the paper matrix was bent and clamped. The mold was then closed, a hinged semicylindrical core acting as cover, and into it a ladleful of molten stereotype metal was poured, by two men who had fetched it from a nearby caldron.

After the appropriate time for solidification had passed the mold was opened and the casting, with its clinging paper matrix, removed. Then the delicate operation of stripping the matrix from the face of the cast was cautiously performed, and the matrix was returned to the mold and repositioned for another cast. Meanwhile, the first cast was placed upon the cylinder of a "cutting-off" device where, after having been nicely positioned and securely

clamped, it was turned beneath a power-driven rotary saw and its riser, or rough upper end, removed.

The saw of this apparatus was so shaped that it left the curved edge of the cast beveled. The cast was then turned and its other end passed beneath the same saw, in order to insure to it likewise a satisfactory clamping surface. The cast was then inverted and dropped, face down, into the hollow of a "shaving-out" device, in which a rotating straight-edged knife served to smooth or plane its inner surface, and to give it an accurate thickness. In order to reduce the surface thus needing to be planed it was customary to construct the core about which the cast was to be made with narrow circumferential grooves, set an inch or so apart. In the casting operation these grooves were reproduced upon the inner surface of the cast as ribs or finishing strips, and furnished a surface which, when planed, was ample to support the cast plate under the pressure of printing.

After it had been shaved the cast was next set, face up, upon a fixed cylinder, or "horse," where two men, with hand-plane and chisel, removed from its edges all superfluous metal, which might otherwise take ink and print. This was called "finishing."

From the finishing horse the cast plate was next carried to a trough and cooled, and thence to the press-room where it was dried and clamped to the cylinder of a press. All of these operations, save only the propulsion of the cutting-off saw and shaving knife, were performed by hand. And for each plate made, every function, from the precise positioning of the matrix to the drying of the finished plate, had to be repeated.

The casting mold was a heavy and clumsy piece of apparatus, which consisted of back and core, a bottom "ring," beneath which the lower matrix-edge had to be

clamped, two side-bars which had then to be laid upon the straight sides of the matrix to hold it in position, and clamps for finally locking the halves of the mold together before it should be stood on end to be filled. Two men were required to insert and position the matrix, and put the mold together, and likewise to take it apart after its contents had cooled, and remove the cast and matrix. Another man was required to cut off the riser, a fourth to shave the plate, a fifth and a sixth to "finish" it, and still another man to dip it. The rapidity with which such a crew could work, with a single casting mold, was at the rate of a plate in every minute and a half.

Thus, in order to produce ten plates from a matrix, or enough to supply five quadruple presses with the plates required to enable them to print a single page, from fifteen to twenty minutes were consumed. If, in an office having five such presses, an eight-paged paper was to be run, eighty plates had to be made, the casting and finishing of which consumed nearly two hours, if but one casting box were used, or half the time if two, as was the custom, were employed.

As the circulations and bulk of newspapers increased presses and pages were added, until at last the Sunday issue of a hundred odd pages, produced in a press-room having no less than sixty unit printing mechanisms, each requiring perhaps sixteen printing plates, ceased to be a rarity. As its pages and presses grew in number, so also did the stereotyping plant of a newspaper in the number of its men and pieces of apparatus. And at last the pressure of plate-making became intolerable in the offices of the large metropolitan journals. Nevertheless, up to the close of the last decade of the last century, the process of stereotyping was carried on in the primitive manner described, and entailed the performance of hard manual labor under injurious conditions of temperature and haste.

In 1900, the Autoplate machine was first set to work in the office of the New York "Herald." Perhaps the most concise summary anywhere to be found of the nature of the change effected by the introduction of machine stereotypy, is in the following extract from the New York "Herald" itself:

"The third department of newspaper mechanics—stereotyping — has remained almost at its starting point, one of the few arts still in the realm of hand labor. It is twenty years since the last improvement was made, and now, in the last year of the century, the art is raised to the mechanical level of its sister arts by Mr. Wood's invention, which does automatically, with few men's hands to aid it, what formerly required many hands and fourfold the expenditure of time. Thus, in the closing year of the nineteenth century, the last act of the mechanising of the printing trade has been accomplished. First came the rotary press in 1860, then the linotype in 1888, and now the Autoplate in 1900."

Speaking generally, the Autoplate consists of a casting mechanism and a series of finishing mechanisms which automatically coöperate in one machine to make the casts and finish them.

From the casting mechanism the plates go automatically through various finishing operations, and when delivered are ready for the press. The entire work of casting, finishing, and cooling the plate is now automatically performed at the rate of eight plates a minute, by a machine which may be run by three men, whose only work consists of supplying its furnace with metal, its casting mechanism with matrices, and of removing the finished plates when ejected by the machine.

By the hand method of plate-making the same amount of work could not have been done by less than thirty-five

men; and even with so large a force the saving of time made possible by the Autoplate could not have been obtained, for eight matrices instead of but one would have been required.

The time saved a newspaper by means of the Autoplate machine may be divided into two parts; that which occurs in the closing of its type-pages which, because of the speed of the Autoplate, may now be held open longer than previously was possible; and that which occurs in starting the presses after the last page is closed. Not only may the first press of a battery be started earlier, but each succeeding press will receive its full complement of plates many minutes ahead of its former starting time. Thus, a large portion of the time that each press formerly spent in waiting for plates is now utilized in producing newspapers, and a great increase of product during the first portion of a run obtained.

It is apparent, therefore, that the Autoplate increases the capacity of the composing-room by giving it more time in which to work, and enlarges that of the press-room by making possible the early starting of presses which otherwise would stand idle awaiting their plates; and thus fewer presses need be used. Furthermore, the Autoplate shortens the time between the receipt of news and its publication, and reduces the cost of stereotyping.

Autoplate machines cost twenty-five thousand dollars each. The New York "Herald" has three, the New York "World" four, the New Tork "Times" two, the Chicago "Daily News" four, and "The Tribune" of Chicago three. Other large newspapers throughout America, Great Britain, and Europe, also, have them in use. Many instances of pay-roll savings, ranging from thirty thousand to forty thousand dollars a year, may be set to the credit of this machine; while in the saving of time, a

still more valuable consideration, some surprising results have been achieved. One of the largest New York daily newspapers, for instance, is now closing its type-pages twenty minutes later than it formerly could, and whereas its whole battery of presses used to require an hour in which to be set to printing, it is now got to work in less than fifteen minutes. The gain of this particular newspaper may be summarized as: a yearly saving of over forty thousand dollars in wages; twenty minutes of added time in which to gather news and advertisements; and the ability to get all of its presses running some forty minutes earlier than formerly, which enables it to catch earlier and more trains and thus vastly to extend the area over which it circulates. In addition to these advantages this newspaper has been able to increase its selling time on the street, and greatly to improve its typographic appearance.

Coincident with the adoption of the Autoplate machine by the dailies of the larger cities there arose a demand, from newspapers of lesser magnitude, for a similar machine suitable to their needs. This was supplied in the Junior Autoplate, a very much less expensive apparatus, but one built upon Autoplate principles.

In many instances newspapers have purchased not one but several Junior Autoplate machines. This has led to the construction of the double Junior, which consists of two Junior Autoplates attached to an elliptical pot, one at each of its ends. The pot employed is usually of sixteen thousand pounds' capacity. The machines are made right and left, and are independent of one another. Such an equipment requires the use of two matrices, one for each machine, and its rate of production is six plates a minute.

Having finished the construction of the double Junior Autoplate, a new apparatus called the Autoshaver was next provided, to shave, cool, and deliver, dry, the plates

made by Junior machines. This consisted of an inclined run-way of stud-supported, flanged wheels, along which the plate might run by gravity, upon its straight edges. At the upper end of this run-way was a receiving station, its exit barred by a cam-worked gate. Next along the route of the plate came a shaving arch, it also having at its lower end a cam-worked gate; then below the shaving arch a water-saddle, the exit of which was likewise barred, and, finally, beyond this a receiving station beneath which rotated a brush to clear the plate of such water as might adhere to its under side.

Driven by the operating mechanism of the machine were cams, which worked the gates, a constantly rotating shaving knife within the arch, clamps for therein securing the plate and the brush. The shaving arch was cooled, as in the Autoplate, by the circulation of water, which went thence to the water-saddle. There, over a series of riffles, the water broke into a cascade so arranged as to compel it to come into contact with the inner side of the plate, which it cooled.

The Autoshaver made six revolutions a minute, and was capable of receiving a plate at each revolution. To use it, it was only necessary that a plate from a Junior should be placed and left on the receiving stand, with its straight edges on the wheels of the run-way. At the proper moment the first gate opened and let the plate run into the arch where the second gate arrested it. There it was clamped and shaved, and at the proper moment released to run out and on to the water-saddle. After having been there held for an instant, and cooled, it was released by the last gate, and ran forward to the delivery stand where, being brought to rest by a stationary stop, it was brushed out, and thereafter stood ready to be sent to press.

Having a capacity of six plates a minute the Autoshaver

was capable of finishing the product of a double Junior Autoplate machine. Thus, it has become the custom to install with every double machine, an Autoshaver. The New York "American," for instance, uses three such equipments, having a combined capacity of eighteen finished plates a minute. In this newspaper office its Autoshavers are so arranged that their finished plates are taken from them by automatic carriers to the various pressrooms in which they are to be used. Thus, a stereotyper touches a plate but once, in transporting it from Junior to Autoshaver.

In concluding, it may lend a touch of human interest to what has been of necessity but a dry relation of mechanical facts if I state that nearly two million dollars' worth of Autoplate machinery has been sold at home and abroad; and that it has been carefully computed that in the United States and Canada there is now being made by its use a yearly saving of over three hundred and fifty thousand dollars.

SMELTING STEEL BY ELECTRICITY[1]

By HENRY HALE

THE enormous quantity of iron ore which is being scooped from the ranges about Lake Superior, dug out of the hills of Alabama and Tennessee, and hoisted from the deep pits of Pennsylvania, has caused the geologist and mineralogist to make startling predictions. Some of them have gone so far as to say that we are approaching an era when iron may rank among the rarer metals because of its scarcity. Even James J. Hill, the railroad magnate and developer of the Northwest, who was one of the first to realize the vastness of the ore deposits in the Superior ranges, has made the prophecy that perhaps within a half century most of the richer ore beds will be exhausted and that we may be obliged to go outside of America for much of the raw material for our smelters and furnaces.

Here, indeed, is a condition which is of the utmost gravity if there is any truth in these predictions. Iron a rare metal? One feels like laughing at the assertion. It seems so ridiculous when a cent will buy a pound bar of high-grade metal, and a nickel will purchase a pound which has been sliced and pressed into nails. Everywhere about us, used for purposes without number, it seems as common, as necessary as the very food we eat. Yet fifty years ago iron was a comparatively scarce metal. If the sayings of its prophets come true, then the Iron Age will indeed have been short, lasting only about a century.

[1] By courtesy of "The Technical World." Copyright, 1907.

When the experts speak of the supply of iron ore, however, they refer only to the kinds which are usually reduced in the blast furnace. Every schoolboy knows that the bulk of this is technically known as hematite — the stuff that looks like so much earth, as, piled in great heaps in the stock yard, it is scooped up by the big self-filling buckets and carried to the furnace cupola by the trolley of the tramway.

Yes, more than three-fourths of the millions of tons of pig iron which like liquid fire flow yearly from American furnaces is composed principally of hematite — perhaps brown, perhaps red — but hematite of some sort, a little of another kind being mixed with it occasionally if a certain grade of " pig " is wanted. Hematite is what they are shoveling up from the Superior ranges at the rate of thirty-five million tons a year. Hematite feeds the furnaces of the South and West. Yet the iron which comes from many of the smelters filled with it is of an inferior grade.

Why does the iron maker use so much hematite? There are two reasons. It is so plentiful and the iron in it can be extracted by the simplest and cheapest processes. So if the product is not so good as that which was made in the charcoal furnaces of our fathers it pays the smelter better than to make a higher grade of metal unless needed for some purpose where better iron must be had.

But suppose the theories of Mr. Hill and those who agree with him are correct, and that the great banks and beds of hematite are being exhausted, is there not other ore?

Yes, mountains of it that would supply every furnace in America for centuries. Why, in the Adirondack mountains alone are deposits which might make northern New York the heart of America's iron industry instead of Pennsylvania and the Ohio valley.

After the painting by ANGELE DELASALLE

IN THE FOUNDRY

Why is it not smelted? Because even in the most modern blast furnace it can not be reduced to metal profitably, since it contains elements which injure the quality of the iron and are not expelled in the chemical action which takes place. So at the present time these inexhaustible stores of ore rich in iron are lying useless, like just so much common earth.

Titaniferous ore, as it is generally called, has been the despair of the iron maker. Found in many parts of the country in such quantities that one bed could keep a score of furnaces in operation, as has been stated, it remains untouched, just as fortunes were thrown away in the old days of gold and copper mining before machinery had been invented to separate the metal held in the tailings that passed through the mill. Some of it contains over seventy per cent of pure metal, but run it through the blast furnace and the resulting product usually contains sulphur, sometimes phosphorus in such quantities that it is not fit for use. These elements can not be entirely removed even by the terrific heat which turns the ore into liquid.

But we may be on the eve of another great industrial revolution. Perhaps we may not need the consumption of the hematite beds, for electricity has come to our aid in trying to solve the problem of making these refractory ores of some good.

During the past year experiments have been made in converting them into iron fit for use, and it can be said at last that experiments have been entirely successful. While but a few tons of iron were run from the crucible it was practically free from any harmful element and of a remarkably high grade. Considering the many and diversified ways we have utilized electricity it seems strange that the application of its intense heat in sepa-

rating iron from the baser substances of the ore, has not been successfully undertaken before, since it has the power of generating such an enormous number of heat units. But that it can perform the work may be stated on the authority of the scientist who reduced the ores, Dr. Héroult, the noted French expert. It may be added that Dr. Eugene Haanel, superintendent of mines for the Canadian government, who witnessed the test corroborated Dr. Héroult's statements.

The scene of this notable experiment was Sault Ste. Marie, Ontario, where opportunity was offered to secure an ampère current voltage from the plant of the Lake Superior Corporation, which generates electricity from water power. With the appropriation of fifteen thousand dollars generously made by the Dominion government a furnace was designed and constructed especially for the purpose.

This furnace is worth describing. It consisted of an iron casing bolted to a bottom plate of cast iron forty-eight inches in diameter. The casing was made in two cylindrical sections to facilitate repairs. To render the inductance as small as possible the lines of magnetic force in the iron case were prevented from closing by the replacement of a vertical strip of ten inches width of the casing by a copper plate. Carbon paste was rammed into the lower part of the furnace up to the bottom of the crucible. The lining consisted of common fire brick, which from the bottom of the crucible up for a distance of a little above the slag level was covered with carbon paste to a thickness of a few inches. The crucible, therefore, consisted entirely of carbon.

The electrodes, imported from Sweden, were prisms of square cross-section, sixteen by sixteen inches by six feet long. The contact with the cables carrying the

electric current to the electrode consisted of a steel shoe riveted to four copper plates which ended in a support for a pulley. The electrode with its contact was supported by a chain passing under the pulley, one end of the chain being fastened to the wall, the other end passing over a winch operated by a worm and worm-wheel. This formed a convenient arrangement for regulating the electrode by hand. The electrical energy was furnished by one phase of a three phase, 2400 volt, alternating current generator coupled to a 300 H. P., 500 volt, direct current motor. A current of 2200 volts was delivered to a transformer of 225 K. W. capacity, designed to furnish current to the furnace at fifty volts.

The transformer was placed in a separate room in the furnace building, close to the furnace. From the transformer the current was led to the bottom plate contact of the furnace and to the electrode contact by conductors consisting each of thirty aluminum cables, five-eighths inch in diameter. To determine the exact amount of current needed for the electrodes used in smelting the plant was provided with voltmeters, an ammeter, and a recording wattmeter. The question of material for reducing the ores was important, as coking coal was not available. It was decided to use briquettes made of coke dust and fire clay, also charcoal as a substitute. The fluxing agents were limestone and quartz.

As less than a half a ton of iron was made at a run, the furnace was kept almost continuously in operation until one hundred and fifty casts had been drawn off, giving fifty-five tons of metal. This was secured entirely from Canadian ores noted for the high percentages of sulphur and phosphorus they contained. They included varieties of magnetite, titaniferous ore, and roasted pyrrhotite.

Dr. Haanel states that such ores, high in sulphur and

not used in the blast furnace, on account of the high percentage of this element, could be smelted electrically with perfect success, yielding a pig iron equal in value to and lower in sulphur than the metal obtained in the blast furnaces from ores free from sulphur and costing three dollars and seventy-five cents per ton in Canada. The resulting metal was not only nearly free from phosphorus, but contained only a trace of sulphur, while the titaniferous iron contained only sufficient titanium to increase its quality.

The conclusions reached by the experts were that magnetite can be as economically smelted by the electric process as hematite. Ores of high sulphur content not containing manganese can be made into pig iron containing only a few thousandths of one per cent of sulphur. The silicon content can be varied as required for the class of pig to be produced. Charcoal which can be cheaply produced from mill refuse or wood which could not otherwise be utilized, can be substituted for coke as a reducing agent, without being briquetted with the ore.

A ferro-nickel pig can be produced practically free from sulphur and of fine quality from roasted nickeliferous pyrrhotite. The experiment made with a titaniferous iron ore containing 17.82 per cent of titanic acid permits the conclusion that titaniferous iron ores up to perhaps five per cent titanic acid can be successfully treated by the electric process. In short, the electric current makes available an enormous supply of ore which can not be successfully reduced to iron by the ordinary blast furnace method.

The question of what it costs, however, is a most important one. In answering this we must take into consideration the quality of the metal which comes from the electrical furnace. Less porous and more compact,

it is far more durable and has such tensile strength yet hardness that it is especially suitable for car wheels, crushing rolls, and other machinery where a very high quality of metal is essential. Those who examined the product of the Sault Ste. Marie furnace agree that it is fully twenty per cent better than the high-grade pig usually sold in the great cities of the East, though made from ore considered little better than worthless in comparison with the favored hematite.

The cost of one electrical horse power per year at Sault Ste. Marie is calculated to be ten dollars, or two and three-quarters cents per day. In reducing one ton of ore, electrical energy equalling ninety-three and one-half horse power was used at a cost of two dollars and fifty-seven cents. The total expense of making a ton of iron including ore at one dollar and fifty cents per ton, and all other items, was ten dollars and sixty-nine cents. The cost of making pig iron in the modern blast furnace varies considerably. While the figures are kept secret by most manufacturers, it is claimed that ore in Alabama is so cheap that a ton of it can be smelted for about six dollars.

The Northern furnaces using range ore from Superior can not produce iron for probably less than seven dollars and fifty cents a ton. Consequently the cost of this electrically made metal was not much higher than the Number One blast furnace grade, remembering that it averages twenty per cent better in quality. But the expense of generating the electric current differs greatly. It is supplied in some parts of the country as low as seven dollars and fifty cents per horse power per year. The invention of more economical water wheels, generators and other apparatus is steadily decreasing the expense of producing the current.

It is worth noting that near the great ore bodies in the Adirondacks are numerous water powers of such extent that they could undoubtedly be employed to create electrical energy at a low cost and in quantities sufficient to establish the smelting industry on a large scale. Eastern Tennessee and other parts of the South also have abundant water power near beds of ores which can not be successfully treated by the ordinary blast furnace. Therefore the prediction that we may be on the verge of another industrial revolution with the aid of electricity is by no means imaginary.

THE HARNESSING OF WATERFALLS[1]

By GEORGE F. STRATTON

FAR up on the slopes of Mt. Rainier, Washington, is a waterfall which, according to the legend, was inhabited by a giant of enormous strength, Menuhkesen by name. From out of the East there came a Genie possessed of such courage and audacity that when he was warned against the terrible powers of Menuhkesen he laughed lustily, and swore that he would call forth the surly giant and make him do his bidding. Summoning his Afrites he gave them orders, and they immediately surrounded the falls, some of them peering through strange instruments and making mysterious signs with their hands; while others measured distances and drove stakes bearing weird and cabalistic symbols into the river banks.

Then the Genie stood on the bank overlooking the falls and shouted: "Ho! — Afrites — dig me here a deep hole!" and immediately they went to work with great activity. When they had dug down one hundred feet the Genie again commanded them to tunnel under the falls. "We will unearth this giant and prove his strength!" he cried, defiantly.

So they dug a tunnel until they reached a great mass of stone underneath the brink of the falls, and here they hewed out a huge cavern and into it carried strange machines and many wheels, fastening them strongly. When all was ready the Genie grasped a great lever and

[1] By courtesy of "The Technical World." Copyright, 1908.

shouted: " Ho! — Menuhkesen — come forth now and get busy! "

Then he pressed down the lever and instantly the spirit sprang out of the falls and, leaping upon the wire, rushed along it with such swiftness that no one could see him. The next moment he was many miles away performing marvelous feats of strength — pushing loaded street cars at incredible speed, turning the wheels in great mills and factories, and lighting the streets and dwellings. In fact, he did whatever the Genie ordered him to do, without an instant's delay or any demur.

The story is true. The name of the Genie is Stroughtson, a Pennsylvania engineer, who developed into a wizard.

All that is to be seen around that wildly picturesque mountain waterfall is a little ten by twelve foot rough stone building — the entrance to the shaft. Down underneath that seventy-foot rushing torrent of water is the cavern, hewn out of solid granite, and in it are the water wheels and electric generators. The inlet water pipe leads from the bottom of the river through the roof of the cavern. The outlet pipe discharges at the foot of the falls and immediately behind them. Transmission wires lead from the cavern down to Seattle, forty miles distant, and over these wires six thousand horse power is constantly transmitted.

Standing at the foot of these falls, in the shadow of the great sequoias, with the rugged mountain slopes tipped with brilliant and ever-present glaciers, the majestic solemnity of all unbroken by any sight or sound of industry, it is not easy to dissociate the legend of the Spirit of the Falls from the Power which is invisibly gliding over the wire leading down through the rocky cañons and dark forests.

In the harnessing and curbing of these mountain streams the utmost engineering skill and ingenuity has been called into play. Often the horse power is situated miles back in such inaccessible wilds that the greatest difficulty has been encountered in carrying the machinery and supplies to the desired spot. At one point in the Sierras men and material were transported across two yawning chasms by means of single wire cables, under which ran a freight basket. Many of the streams utilized are small, but by proper diversion and concentration give a great head of water — five or six hundred feet being not at all uncommon.

The most striking illustration of the power of a small stream is shown in San Juan County, Colorado. The Animus River, in its course between Silverton and Durango, — a distance of twenty miles, — has a gradual fall of about fifteen hundred feet. Although called a river it is but a mountain stream, tumbling over little falls and through rock-strewn gullies; at no point showing more power than would be sufficient to drive a very modest saw- or grist-mill. But the genius of science has so cunningly diverted it and concentrated its energy, as to develop at last no less than forty thousand horse power.

A dam is built a few miles below Silverton and the stream turned into a wooden conduit or flume which is only six by eight feet in size. It will be seen that it must be a very small stream whose waters can be run through such a restricted channel. Over valleys and across chasms; sometimes on high trestles; sometimes through deep cuttings, the flume carries the captive river for ten miles, finally discharging it into Cascade reservoir, a natural basin three miles long and three-quarters of a mile wide. Here it gains some little accession from the waters of a small creek, and at the lower end of the reser-

voir it again enters a flume, this time a steel tube only four feet in diameter. The current is now rapidly increased; this four-foot tube must carry as much water as the six-by-eight conduit, consequently its work must be done much faster.

Two miles brings it to the edge of a cliff near Durango, one thousand feet in depth, and the pipe turns over the edge making a perpendicular drop of that distance, conducting that solid, four-foot column of water, one thousand feet in height, into turbine wheels operating electric generators of forty-thousand horse-power capacity.

This is the biggest perpendicular fall in the world; it is the most forceful four-foot drive of water known. A rifle bullet fired into it glances off as from solid chilled steel; a jet from it no bigger than a penholder will drill a hole through sheet steel in a few moments. At the reservoir a dainty fly line may be played in the water — at the flume no mortal man could thrust a bayonet one inch into it.

A United States trooper essayed, on a wager, to cut a two-inch stream with his sword — a shattered weapon and broken wrist were the result.

From the four-foot steel pipe, nozzles five-eighths of an inch in diameter conduct the water into the turbines, which are of the type known as "impulse" wheels, and the speed of which is from three to four thousand revolutions per minute. The speed of the jets of water emerging from these nozzles is no less than twenty-five thousand feet — or over four miles per minute.

Note how science still further concentrates and controls the giant it has evoked. That forty-thousand horse-power force, making that mighty plunge over the cliff, is met by magical machines and switched into a copper wire but little larger than a lead pencil. Forty

feet of that unyielding steel flume is a load for a heavy freight car; forty feet of the copper wire is a load for a ten-year-old boy.

At one moment the power is in that roaring, headlong, terrific plunge — the next it is miles away, invisible, noiseless, and mysterious, illuminating great arc lamps running heavy cars, and — to come from great to small — whirling dainty fans, or — cooking an egg!

And the little stream, freed from its captivity, widens out, rippling merrily over the rocks, perhaps to be sometime "rounded up" again and made to give a similar demonstration of strength farther on.

For, although the refrain of an old song says that "the mill wheel will not turn with the water that has passed," the assertion is refuted by many of the modern hydro-electric installations.

In the Niagara Gorge is a power plant which is using the same water three times. A canal was dug to conduct water from above the falls along the top bank of the gorge. Before the days of the electro generator a water wheel was installed forty feet below the canal level — that being the limit of head which water-wheel manufacturers, at that time, felt able to handle. A few years later another wheel was placed thirty-five feet lower, using the water which came from the first. And recently a third turbine has been installed at the foot of the gorge, still using the same water and two hundred feet below the canal level.

A view, to-day, of the Niagara Gorge shows a number of power plants at various elevations up the cliff, and the dates of the building of these plants can almost be determined by their distances from the top.

The greatest power houses in the world are, as might be expected, at Niagara. One of these — the plant of the Toronto and Niagara Power Company — is situated

on the Canadian rapids, above the Horseshoe Falls. A pit has been sunk in the bank one hundred and forty-five feet deep, at the bottom of which are the water wheels — which thus get a head of water of about one hundred and forty feet. The outlet is remarkable. It consists of a tunnel, excavated under the bed of the river and emerging, immediately behind the Horseshoe Falls and, of course, at their lowest level. This plant develops one hundred and forty thousand horse power.

A report made by the Commission which was appointed to examine the conditions at Niagara gives some very interesting facts. The total energy of the falls is estimated at seven million five hundred thousand horse power, equivalent to the latent energy of all the daily mine of coal in the world — something over two hundred thousand tons. Concessions have been made to power companies on both sides of the river, amounting to something over one million horse power. But it will probably be many years before all this is taken up. At present machinery is installed to generate about three hundred thousand horse power.

But, although Niagara is gigantic, it does not surpass in interesting peculiarities a great many other water powers. From many points of view the greatest and most interesting single power plant in the world is situated on the Necaxa River, in Mexico. In a certain stretch of three miles this river makes a drop of over three thousand feet. Six thousand men have been employed for three years upon this section. Four dams have been constructed, ranging from sixty-six to one hundred and seventy-seven feet in height. To conduct the water to the power house there are four and one-half miles of mountain tunnels, five and one-half miles of eight-foot pipe, and seven miles of thirty-inch steel pipe. Machinery

is in place to develop eighty thousand horse power, and provision is made to install sufficient to develop two hundred thousand horse power.

The current is transmitted over one hundred and eighty miles to the city of Mexico. Three thousand steel towers carry the transmission cables, and thirty-six patrolmen are on duty, day and night, watching the line. The total cost, when finished, will be eighteen million dollars.

Although high head powers are usually much more interesting and picturesque than low head, there are, nevertheless, some very strange installations at low head. On the Patapsco River, in Maryland, a somewhat sluggish river but having a great volume of water, a dam has been built and one thousand six hundred and fifty horse power utilized. But, standing by that dam, no sign of power house or machinery is visible. All is contained within the dam itself, which is hollow and divided by interior buttresses into chambers for the water wheels and generators. Water is taken from the upper side of the dam and discharged at the lower side.

Here, again, the visitor — be he engineer or layman, poet or plumber — can not fail to be impressed with the scene. The banks are wooded and wild, showing no buildings or machine shops. A thin sheet of water is gliding over the spill-way and you are only conscious, because so informed, that a mighty power is being evoked beneath that mass of water. Mysterious, unseen and unheard here, it is gliding down the wires to the distant city, there to break into strident action at the pressing of a button — the turning of a switch.

Another unusual development of low head power is seen on the Feather River, California. The west branch of this river makes a big horseshoe bend twenty-five

miles above Oroville, coming within three miles of itself again. A mountain intervenes, but this has been tunneled and the water diverted from the upper stretch of the river through the tunnel into the lower reach. And upon that black, rushing, underground torrent the wheels and generators will be placed. The Strong Spirit of the waters will become the Spirit of the Mountain, and will "get busy" at the turning of a wrist.

The head, or height, of water available is always one of the most important points in determining the site of a power house. A comparison between two extreme instances will show this importance. At Albany, in Georgia, is a river flowing at the rate of twelve hundred cubic feet per second. A dam was built giving an available head of twenty-three feet, and three thousand horse power is secured. On the Stanislaus River, California, is a stream running three hundred cubic feet per second — one-fourth as much as the Albany water — but with a fall of fifteen hundred feet, and the power obtained equals twenty-five thousand horse power — over eight times as much as the Albany power. These high heads in mountain streams are, however, usually secured only by the construction of expensive flumes. The stream is dammed high up the range and led into a timber or steel flume; thus, instead of wasting its energy by trickling down the mountain side, it is conducted by an easy grade to some cliff at the foot of the range, where the entire drop is made available at one time.

Some of these flumes are from twenty to thirty miles in length. They cross valleys and cañons upon great trestle works. They circle the sides of mountain spurs, and, in many cases, tunnel through them. Usually they are simply square troughs constructed of heavy planks, but, as they approach the power house where the flow

becomes rapid and the pressure great, steel pipes are used.

The water wheels used in these great hydroelectric plants are fine illustrations of the readiness with which American engineers and manufacturers adapt themselves to new conditions. Until electricity furnished means of transmitting power over great distances, water power was confined to the very narrow limits of individual users, and the wheels were, consequently, of very small power.

To-day, however, turbines of from five to ten thousand horse power are by no means uncommon. At Niagara Falls there are four turbines, which develop nearly fifteen thousand horse power each, and which are, probably, the largest in the world. An article in the Philadelphia "Record" referring to these turbines, says:

"The building of these machines marks another epoch in the country's history, because their design, as well as their manufacture, is wholly American, and all the engineers and workmen concerned are American, and graduates of American schools and shops, though the work is being done for a company in a foreign nation — Canada — and the contract was awarded against the competition of the largest builders all over the world."

Such a wheel as this is a giant, not only in power but in stature. Its weight is six hundred and twenty thousand pounds for the turbine alone, the electric generator being a separate machine, although directly connected to the turbine shaft. A monster like this, doing the stupendous work of fifteen thousand horses, requires much water. It is supplied by a pipe eleven feet in diameter, through which a solid column of water flows, at the rate of ten feet per second.

These great wheels are known as reaction wheels, and are generally used only when the height of the water is

not very great. For high heads, particularly in the western mountains, the impulse wheel is generally used. This is very much smaller than the reaction type, but what it lacks in size it makes up in speed — the necessity for this lying in the fact that water coming from a height of six, eight, or ten hundred feet comes very rapidly and must be taken care of. Only very recently has the world awakened to the latent possibilities of usefulness in many apparently insignificant streams. A review of what one comparatively small plant is doing in Washington shows a surprising amount and diversity of utility from this power. The Snoqualmie Falls, near Seattle and Tacoma, are about sixty feet in height, and machinery has been installed to develop ten thousand horse power. This power is running the trolley cars at Seattle which carry forty million passengers yearly. It runs the cars at Puget Sound, carrying over one million passengers yearly between Seattle and Tacoma, and it also operates the Seattle and Renton railway with twelve hundred thousand passengers yearly.

It grinds over twelve thousand bushels of wheat daily; treats seven hundred and fifty tons of ore daily at the Tacoma smelter; furnishes power for the largest iron works in the Northwest; for the metropolitan press of Seattle; for the Washington Shoe Company, and for the American Steel and Wire Company. It runs scores of small industries in Tacoma and Seattle; it supplies the entire city lighting of Tacoma, and it furnishes power and light to Renton, Kent, Puyallup, Sumner, Swansea, Issquah, and Auburn.

And yet, that mysterious and mighty power glides silently into those cities, over small wires from one of the most beautiful falls on the coast — the home of another Menuhkesen.

GREAT ACHIEVEMENTS IN BRIDGE-BUILDING[1]

By FRANK W. SKINNER, C. E.

BRIDGE-BUILDING is one of the oldest of the engineering arts, and yet in the principles and methods which it follows to-day it is one of the newest. It is impossible to say when the first bridge was built, so shrouded in antiquity is the date. But the first metal truss bridge, the erection of which marks the beginning of modern methods of construction, was put up no longer ago than 1840. Almost all the great bridges of the world have been built within the past quarter century. In 1863, a bridge was thrown across the Ohio River with a span of three hundred and twenty feet, then an unprecedented length. At the present time the limit of a single span has been extended to one thousand seven hundred and ten feet in actual construction, while others of nearly three thousand feet have been designed by able builders and undoubtedly will be erected.

It may be seen, therefore, that in spite of its newness, bridge-building, as it is carried on to-day, is not an undeveloped art. Within the space of an ordinary lifetime it has attained to a perfection and a final standard that is comparable with the progress of architecture through all the centuries since the time of the pyramid builders. It is safe to say, indeed, that, as an art, bridge-building has reached a point where it must await the invention

[1] By courtesy of the author and "McClure's Magazine." Copyright, 1901. Revised and brought down to 1910 by the author.

of some new material to afford it scope for any radical improvement.

The great factor in this advance has been the improvement in the manufacture of steel and its extension to this branch of construction. Bridges may be built of materials other than steel. Many such have been built, and are now in use. Stone was one of the early materials employed, but stone has never been extended to spans of more than two hundred and fifty feet. Wooden bridges have been built with spans above two hundred feet in length, while others of wood and iron combined have exceeded three hundred feet. For all of these materials comparatively low limits are defined by the rapidity with which strains and weights increase with the increase of span.

The same consideration applies to steel, but for the performance of any given duty steel is actually much lighter than timber. Steel has no competitor as a material for the longest spans at the present day. Even with steel, however, the cost of construction increases approximately with the square of the increase in span. This factor of cost, rather than mechanical difficulties, is likely to set the final limit to the length of bridge spans.

While steel has been the chief element in making possible the big bridges of to-day, it has been by no means the only one. The invention of powerful tools and hydraulic machinery, which forge and lift and rivet massive pieces that previously could not have been made or handled, has contributed to the same result. Every process in the production of these immense structures is carried on now on a scale undreamed of thirty-five years ago.

The methods of modern bridge-building form a subject on which it is difficult to generalize effectively. The

conditions surrounding the erection of two great bridges are never alike. The engineer's problem is always one of adaptability, while new and perplexing difficulties must be met and overcome in every fresh undertaking. The building of each immense span must be looked upon and judged as a separate engineering feat, rather than as an incident in the general industry. The location of the structure, the conditions surrounding it, and the general purpose for which it is intended, are the fixed factors with which the engineer sets about his task. With these in mind, he plans the finished work, and the results are such as to astonish those unfamiliar with the progress attained by engineering art.

The truss, or skeleton, of separate steel pieces must be so arranged as to convey to the abutments in proper proportions the loads from its own weight and the weights it is intended to carry. The impact and vibration from the vehicles which are to cross it must be determined. The strain of wind and storm beating against it must be calculated. The almost irresistible expansion and contraction of the mass of metal under the influence of summer heat and winter frost must be provided for. All these problems are solved by the computer in his plan. His designs predetermine to the fraction of an inch how much a thousand-foot span will deflect under a load of one or twenty locomotives. It is all figured out before a bar is cut or a stroke given toward actual construction.

After verifying the designs, which are in the field of the mathematician, the next step is to put these designs into form, a task which falls to the lot of the metallurgist and steel maker. This is by no means an unimportant part of the process. The steel which is to form the bridge is turned out in bars, many of them so strong

that singly they could sustain the pull of fourteen thousand horses hauling on common roads, so ductile that a short bar will stretch half its own length before giving way, so tough that great bars when perfectly cold can be tied into hard knots without cracking.

Following the plans, the bars, plates, and shapes are formed into flexible chains, the weakest links of which can sustain loads of a million pounds each; into huge girders which alone could carry the heaviest trains across an ordinary street; into riveted braces so large and long that eight-oared rowing shells might easily be stored in them. To join the separate parts together, solid steel bolts as large as stovepipes are provided. And the holes for which these bolts are destined are bored and polished to an accuracy of a hundredth of an inch in position and diameter. These features of the work are the best measures of the tools, hydraulic forgings, and electric machinery employed by the manufacturers, who have capital aggregating many millions invested in shops equipped solely for turning out bridge material.

The outcome of all this is the finished bridge in the form of a hundred carloads of rods, bars, braces, girders, columns, and boxes of rivets. They are dumped down at some spot, perhaps in the heart of a wilderness, where the problem of handling them may become one of appalling difficulty. From them the builder must evolve his bridge.

The huge, inflexible pieces must be fitted together with watchmaker's precision, and the one-hundred-thousand-pound masses must be swung high in air to form part of a self-sustaining structure over a hitherto impassable torrent. Or perhaps the situation is of another sort, and the acres of forged and riveted members are destined to span a river in angry flood or with treacherous bottom,

or to replace a weakened structure without interrupting the traffic of hundreds of daily trains or fleets of vessels.

These things and others still more difficult are accomplished by the bridge erector, who, with a few diagrams, some carloads of steam engines, ropes, tools, timbers, and a few score men, rapidly and safely assembles the great fabric, in summer or winter, storm or flood, with a resourcefulness, skilled ability, and ready courage that can hardly be matched by any other calling.

The most simple and usual way of erecting the superstructure of a great bridge is to build underneath it a temporary wooden platform, called a "falsework." On this the different members of the trusses are supported until they can be connected together and enabled to sustain themselves. Such a falsework costs many thousands of dollars, and in itself is often an engineering work of no small magnitude. It is composed ordinarily of rows of heavy piles driven deep into the river bottom, and carrying above the water level story after story of framed timber columns and beams bolted and braced in every direction. On top of this edifice are wide steel tracks, on which rolls a tower of steel or wood called a "traveler." This traveler does the heavy work of construction, its booms and tackles, operated by hoisting engines, swinging the great steel pieces into position.

These falsework structures must be solidly built, for they are called upon to endure enormous strains. With all care in their erection, they are sometimes wrecked by floods of ice, or by the scouring of the river bottom beneath them. Sometimes the disaster comes suddenly, and the workmen have barely time to escape. Sometimes the danger is known well in advance.

In these disasters, hairbreadth escapes for the men are of no uncommon occurrence. In one wreck of an Ohio

River bridge, in which many men were killed, different portions of the span fell successively from one end to the other. One man fleeing toward shore just kept pace with the falling structure, so that he was all the time running up an incline. At length the collapse of the falling timbers overtook him, and he was knocked into the river, whence he was rescued by his comrades on shore.

An accident equally remarkable and more ludicrous occurred during the building of the Washington Bridge across the Harlem River, in New York. The plate girder arches of this bridge were erected on falsework nearly one hundred and fifty feet high, with wide openings in it to permit the passage of boats and trains. In the course of the work a man fell from near the top. He struck head first in the shallow water, and stuck fast in the mud, his feet waving signals of distress in the air until he was pulled out, when he was found to be only slightly injured.

In building the Poughkeepsie Bridge across the Hudson, the depth of water and mud was so great that piles one hundred and twenty feet long were required. As such dimensions could not be secured from single trees, each pile was composed of two large tree trunks spliced together. Above the water level these were capped with square timbers, on which was erected a massive body of symmetrical timber work of remarkable proportions. It extended to the lowest part of the bridge span, one hundred and twenty feet above the river level. Upon it was reared a tower more than one hundred feet high, which carried the tackle for assembling the trusses. In its entirety this temporary structure, built merely to facilitate the erection of the bridge, attained a height greater than that of the majority of "sky-scrapers."

While the Poughkeepsie falsework was one of the most

lofty ever constructed, one of the most massive was built at Memphis during the erection of a railway bridge across the Mississippi. The bridge itself is the longest truss span in America, and with two exceptions the longest in the world, its span being seven hundred and ninety feet. The foundation of the falsework was formed by rows of hundred-foot piles driven through sixty feet of water and twenty feet of sand. On these was built a superstructure eighty-five feet high, carrying twenty lines of heavy stringers to sustain the weight of the bridge and traveler.

Where it is impossible to drive piles in the river channel, temporary trusses are sometimes supported on the permanent and temporary piers from which to erect the superstructure. This was done in the case of the Plattsmouth Bridge across the Missouri. Three short spans with intermediate timber towers were used for the erection of each main span. After the completion of the latter, the temporary structure was lifted on boats and towed around into position to be used on the next span This was a hazardous undertaking, but it was successfully accomplished.

When it has been found difficult or impossible to erect a bridge on the actual site which it is to occupy, the problem has sometimes been solved by putting the span completely together on shore, and then floating it into position. This operation is among the most spectacular connected with bridge erection, as it also is one of the most hazardous. Notable among those constructed in this manner is the Hawkesbury Bridge, in Australia. In this case, the construction was so dangerous that only American engineers were able to guarantee its satisfactory performance, and an English contract was unwillingly awarded to a prominent New York company.

More difficult still was the erection of the Coteau Bridge, near the Coteau Rapids, in the St. Lawrence River. Here the task was complicated by the depth of the water and the swiftness of the current. The bridge contained fourteen spans, each more than two hundred feet long. These spans were erected on shore, and skidded on greased rails to the tops of towers built on the decks of a pair of scows braced together like a catamaran. The unwieldy craft and its top-heavy load were in each case floated several miles down the swift current, anchored in thirty feet of water, and the span lowered to its seat of masonry.

The largest span ever erected in this manner was five hundred and twenty-three feet long. It forms part of the Brunot Island Bridge across the Ohio, near Pittsburg. The span was first assembled on piles near the shore. Then nine large barges, partly submerged, were floated beneath it. Timber trestles were built from their decks to the lower side of the steel girders. When the water was pumped out of the scows, they lifted the entire structure clear of its former supports. The long, flexible line of boats, carrying the great mass of steel and timber one hundred and fifty feet high and weighing thirty-six hundred thousand pounds, was pulled out into the river, revolved through a quarter circle, and towed by steamboats to the bridge site, where the span was deposited on top of its eighty-foot piers.

An unusual method was adopted for replacing a heavy two-hundred-and-thirty-six-foot span carrying the main line of the Pennsylvania Railroad across the Schuylkill River. Temporary timber piers were built in the river above and below the old span at both ends. These piers supported a low bridge, the top of which formed a platform on which the new span was assembled.

Double sets of long steel rails were laid across the tops of the piers at both ends, and one hundred and fifty solid steel rollers placed between the top and bottom rails of each set.

The new and old spans were lowered to rest on the upper rails, and four powerful tackles being attached to them, and operated by as many hoisting engines, moved both spans sidewise until the new span completely displaced the old one and was ready to receive traffic. Then the low bridge which had formed the erecting platform was rolled across underneath, as the main spans had been, and was used to support the old span while it was being removed. This operation involved moving nine hundred and fifty tons twenty-seven feet, and it was accomplished in two and one-half minutes, in an interval between the crossing of two trains, an achievement which had then never been paralleled.

In foreign countries a favorite method of erecting bridges is to assemble all the spans together in one continuous structure on shore at one end of the bridge, and then to push the whole mass forward on rollers till it advances successively from pier to pier, resting on rollers on top of each, and finally attaining its required position. The protrusion is usually effected by gangs of men with long ratchet levers laboriously turning the rollers.

The longest trussed spans in the world are two one thousand seven hundred and ten foot cantilevers of the famous Forth Bridge in Scotland — a gigantic structure which weighs over one hundred million pounds, which was seven years in building, and which cost sixteen million dollars and scores of human lives. From each of the three main piers rise huge wedge-shaped steel towers that cover spaces nearly a city block in area and reach three hundred and sixty-one feet above the water. From each side of

each tower there extends a pair of great curved trusses, six hundred and eighty feet long, that balance each other, and, approaching the ends of corresponding arms from the next piers, sustain between them separate complete bridge-spans of three hundred and fifty feet that are there suspended above the loftiest topmasts of the ocean ships passing below.

These overhanging arms that are unsupported at their outer extremities are cantilevers. They have been adopted for all the greatest trussed spans, because by their use the opening can be virtually subdivided into three parts, each having its separate trusses, and thus can be made lighter, and can be more advantageously built. In this country the largest cantilevers have been built of struts and ties and beams manufactured at the shops and rapidly fitted together with single large bolts or pins, but in the Forth Bridge the principal members of the trusses are enormous steel tubes made of thick plates, curved, fitted, and riveted in place. Large shops were built on shore, special machinery was designed for them, and the manufacture of the bridge progressed there adjacent to its erection.

First the inclined posts of the main towers were built up from the bottom. Each of the four columns forming a tower is a twelve-foot tube large enough to run a railway train through. These columns were built together and braced against each other, while powerful hydraulic presses inside of them supported and constantly lifted in advance pairs of heavy iron girders, themselves as massive as ordinary railroad bridges, and from these girders the machinery and materials were supported. Following them, circular cages enclosed the tubes and supported the men and machinery that riveted the cylinder plates together.

After the towers were completed the cantilever arms were extended from both sides, and sustained themselves at all times by their own rigidity without requiring any support. The curved arch-like top and bottom pieces of the trusses were also twelve-foot steel tubes, which were ingeniously built out in their approximately horizontal extensions by means of a sleeve-like framework that projected beyond the end and was furnished with derricks for assembling the steel plates of the cylinder. As fast as the sections were fitted together the rear part of the enclosing sleeve was removed and built on in front, so as to advance it enough to support the next section, and so on.

The four great railway bridges across the Niagara River gorge stand as an epitome of American bridge-engineering. They illustrate the development of bridge-construction during the last half of the nineteenth century, and afford examples of all the types of heavy spans. These bridges cross a chasm more than two hundred feet deep, at the bottom of which water of great and unknown depth rushes along at tremendous speed. It is said that the first communication between the opposite banks was established by flying a kite across, and that the string of this kite served to pull across a rope, which in turn conducted above the stream the cables sustaining the light highway bridge erected in 1847. In 1855 this bridge was replaced by the famous railroad suspension bridge, the first of its kind. The successful creation of this structure was a monument to its builder, Roebling, and vindicated his designs, which had been pronounced visionary and impossible by Stevenson and other eminent English engineers.

The general construction of the suspension bridge, and the manner in which its trusses were supported from

four great cables, each formed of three thousand six hundred and forty parts of an endless straight iron wire wrapped together into a cylindrical bundle ten and one-quarter inches in diameter, have been so often described as to be generally familiar. But the first building of the bridge was scarcely more remarkable than the manner in which it was from time to time repaired and reconstructed.

After the bridge had been in service for twenty-two years, it was found that some of the small wires of the main cables were being weakened by rust. The defective portions were removed, and new pieces were spliced in under strain, and so delicately adjusted as to carry their exact proportion of the total load. A little later it was discovered that, while each cable had a resisting strength of six million pounds, the strength of the anchor chains was less than three million five hundred thousand pounds. To remedy this discrepancy the anchor pits were opened, the chains which supported the whole weight of the bridge and of the constantly passing trains were disconnected, and new bars were added to them. The strains were adjusted to the new portions by heating the iron and carefully measuring the consequent elongation until exactly the right point was reached.

In 1880 the old wooden stiffening trusses and floors were removed piecemeal, and replaced by steel, without impairing the integrity of the structure in the slightest. A few years afterward, it was found that the temperature elongations and contractions of the main cables had bent the towers back and forth until many of their solid stones were cracked and broken. These stones were removed and new ones inserted in their places.

In 1886 new steel towers were built up outside the older ones of masonry, and the cables were lifted up by

hydraulic pressure and deposited in new seats. All of these changes, affecting nearly every portion of the bridge, were made without interrupting the traffic across the structure, without serious mishap or the loss of a life. They form a series of brilliant achievements unprecedented in the annals of bridge-construction or repair. The later ones were designed and executed by the late Mr. L. L. Buck, afterwards the chief of the new East River Bridge in New York, which, with its six railway tracks, foot-walks, and bicycle paths, was when first completed, the greatest, though not the longest, span in the world.

Notwithstanding the repeated improvements in the Niagara Suspension Bridge, it finally became inadequate for the increasing volume of railway traffic. In 1896–97 it was entirely replaced by a new structure, built on the same site, and without interrupting traffic. This seems like an impossible feat, but the principles on which it was conducted are well established in bridge-building, and are well understood by bridge-engineers. The span of the massive five-hundred-and-fifty-foot steel arch was built out, panel by panel, from the opposite abutments in the form of cantilevers. These cantilevers were partly supported by forged steel bars temporarily anchoring their upper parts to steel beams bedded in masses of concrete which filled pits blasted out of the solid rock. The work advanced from both sides of the river at the same time, and the materials were carried into place by steel travelers running on top of the completed portions of the growing structure.

Thus, the old bridge was gradually enclosed by the upper part of the steel arch, which surrounded it on sides and bottom, but did not touch it or interfere with its daily functions. The two semi-arches were built so that

their extremities would be a little too high and too far apart when the final joint between them was reached. They were then united by slightly extending the anchor chains from each side. It is a delicate matter to lengthen chains that are under a strain of more than a million pounds, but it was accomplished by means of an ingenious screw-toggle arrangement. The two parts came easily together; the bridge was complete, and took up the duties of the older structure without the slightest hitch.

A few hundred feet above this bridge is the famous Niagara Cantilever, one of the first of this type to be built. Just below the Falls is a beautiful steel-arch bridge of eight hundred and forty feet span and one hundred and thirty-five feet rise. It is by far the longest arch in the world. It was erected cantilever fashion much as was the one already described.

One of the loftiest great trussed bridges in the world is the Kaiser Wilhelm, near Müngsten, which carries a double-track railway across the valley of the Wüpper, three hundred and fifty feet above the stream. It has a clear span of five hundred and twenty-five feet. The manner in which this bridge was built illustrates typical European methods. The first step was to build a temporary service bridge across the river on steel and timber towers about a hundred feet high. Large shops and work-yards were established on one bank. Inclined planes and electric cable roads were run from both ends parallel to the bridge, to serve for the distribution of material. Huge timber towers were built at each end of the arch for falseworks, from which the permanent steel towers were erected.

In this country much of this work would have been dispensed with entirely, and the towers would have been made self-supporting during erection. After the towers

were completed, their tops were tied back with steel cables to the special anchorages provided, and then the arch trusses were built out and up from their springing lines at the abutments to the crown. While building, the semi-arches were partly sustained by steel backstay cables. The trusses were built out panel by panel without further support until they met at the center. Then the huge semi-arches were tipped forward a few inches by lengthening the anchor lines, so as to secure the exact space required for the last pieces in the key of the arch. Finally, the strains on the towers were adjusted by hydraulic presses at their feet.

One of the most interesting factors in modern bridge-building is the workmen. Their experiences aloft tend to make them forget the matter of altitude entirely, and they will unhesitatingly assume the most daring risks in the doing of their work. But many of their exploits that are so nerve-shocking to the inexperienced observer seem very simple matters from the workman's point of view. They become so expert, cool-headed, and sure-footed that they very seldom fall. They will run on a beam a few inches wide and a hundred feet above the water; will swing a sledge while standing on an ice-covered timber projecting at a dizzy altitude; or will walk across a springing plank when the wind blows so fiercely that they are compelled to lean far out against it to keep their balance. They will pose in the most startling positions whenever the work is being photographed: one instance, a workman actually stood on his head, on the top of a derrick, a hundred feet above the water, in order to demonstrate his nerve and indifference.

In replacing the Niagara Suspension Bridge nearly all of the workmen employed were floating mechanics and laborers, who had no previous knowledge of bridge-work

yet they did the work well, so perfectly and simply was it planned and so skillfully was it directed. Some of the men, when they applied for work, requested permission to stay mainly on one side or the other of the boundary line between the United States and Canada which the bridge crossed, because on the opposite side their liberty had been jeopardized by various misdemeanors.

Notwithstanding the great height at which the men worked above a maelstrom from which escape would have been impossible, most of them soon grew unconcerned and some of them, indeed, vied with one another in reckless daring. So many valuable tools were dropped from the bridge that some of the more careless losers were discharged. Consequently, one day, when a man dropped a wrench two hundred feet to the water's edge, he foolishly started to recover it by climbing down hand over hand on a steeply inclined thin wire cable nearly five hundred feet long.

He had no sooner begun his insane exploit than a rival, not to be outdone, started, out of sheer bravado, to descend an adjacent rope. After going a few feet they tried in vain to return, and it seemed to their horrified companions on the bridge above that human muscles could not endure the increasing strain of their long journey. The foreman instructed them how to climb more easily and what to do at the bottom, accompanying his orders with violent abuse, wisely bestowed to divert them from the fright that added to their danger.

By nothing less than a miracle both men held on until they had crossed over the water. Then one of them, watching his chance, dropped safely into a tree-top. The other finally gave out, and fell a considerable distance to the ground. But both escaped practically unhurt.

Instead of being received as heroes, however, both were immediately discharged by their foreman. No serious accidents occurred on the bridge, but there were some hairbreadth escapes, as when one man, carrying in his tongs a white-hot rivet, ran along a well-oiled, narrow iron plate at the extreme edge of the bridge and fell violently on his face. He grasped the slender chord instinctively with arms and legs, rose, carried the rivet to its destination and helped to drive it.

Recent as are the structures above described, all of them built within the remembrance of the leading engineers of to-day, they have been so much surpassed in magnitude, capacity, and methods of erection by more than half a score begun and many of them completed, within the last ten years, that they are now historical and in many respects quite superseded, although of unimpeachable excellence for the requirements they were designed to meet.

The weight of locomotives and cars and the speed and frequency of trains have been so much increased that structures perfectly competent for the old service have become inadequate for present demands and have been replaced, while new bridges are proportioned not only for the heavy duty now required, but with a considerable margin for a like ratio of increase in the future. This necessitates great weights and new methods of erection for moderate-length spans, and the success and rapidity with which they have been constructed and the increased economy of cost have inspired confidence in the financial dictators to meet the demands of commerce with a number of splendid spans so long and so heavy as to approach the limits of existing facilities of manufacture, transportation, and erection. These limits will be extended as each advance is made sure, but the corresponding diffi-

culties and cost increase so much more rapidly that the requirements will be imperative before they are financially justified.

The Kentucky River Bridge, the real father of long-span cantilevers, built in 1875, was one of the most brilliant and daring of engineering constructions. Entirely without precedent the engineer, confronted with the problem of erecting his three long spans over a gorge nearly three hundred feet deep, abandoned all falsework, and anchoring to the bases of heavy masonry towers opportunely existing at the ends of the bridge, built out his otherwise unsupported cantilever arms, reacting against the solid rock of the great cliffs on both sides of the river. Foreseeing that the excessive stresses thus produced would be too great for the trusses, he stopped halfway to the tall steel towers waiting on the river banks to receive them and the channel span, and there temporarily supported them on intermediate wooden towers. With reduced stresses he resumed the erection, built out the overhanging trusses to rest on the steel towers, and thence on again to meet in mid-channel. After more than thirty years of service this bridge has just been replaced by a new superstructure of about the same length erected on the old foundations without in any way interfering with the railroad service.

New steel towers, longer and wider than the old ones, were built outside the latter, and on them were erected three new spans, also inclosing the old ones, with room enough inside for the trains to run on the old track underneath the new double track, which was completed ready for service, and traffic shifted to it, before the demolition of the old bridge was begun. As the old spans were not strong enough to carry traffic and the erection weight of the new spans, the latter were built out in both

directions simultaneously from both towers, as double-balanced cantilevers, until the opposite parts of the center span met above mid-channel, and the shore spans reached temporary support on intermediate falsework towers, almost reversing the process of original construction.

The Coteau Bridge superstructure, too, has just been replaced by new spans, and again the engineers were unable to devise a better method of erection than was employed in the first case, although the requirement that heavy train service should be maintained during the renewal added considerably to the difficulties of the proposition. The new spans, eight at a time, were erected complete at the required height, at the water's edge, about three miles from the site, and as fast as completed were rolled sideways out to the ends of a pair of piers built at right angles to the shore, so that barges could be floated between them, under the outermost span. The water ballast being pumped out, the barges rose and lifted the span, which was towed to the bridge site simultaneously with the removal of the old span it was destined to replace: that was raised from its piers and floated off on barges in the same manner. The old span was towed to the erection yard and deposited on the piers, effecting the exchange of old for new span in about three hours, without interrupting the train service.

The Poughkeepsie Bridge has not been wholly replaced, but portions of it have; the strength of the main spans has been greatly increased, and its anchorages have been reinforced without interfering with the very frequent train service over it. In the very high approach spans some of the trusses have been taken out, sent to the shops, rebuilt, and replaced in the structure; some have been replaced by new girders, and the tall steel towers have

had additional columns and girders combined with the old ones, while the anchorages which receive the thousands of tons' reaction from the cantilever arms of the great spans have had their huge steel anchor chains reinforced by new bars put in and adjusted to bear their exact proportionate amount of the varying stresses, all without accident and without interruption to the traffic. Much of the work was done by a pair of very powerful derrick cars, without which it could scarcely have been accomplished. One track was abandoned to the erectors, while all traffic was carried over the other track, and the old trusses and girders were swung bodily out and carried off by the derrick cars, which brought in the new ones and set them where they could quickly be slid into permanent position and support the track to which trains were diverted while the other side of the span was rebuilt.

The greatest bridges in the world, considering their combined weight, capacity, and length of spans, are those across the East River, New York. The Queensboro Bridge, proportioned for six tracks, two driveways, and two sidewalks, has a capacity of two hundred million car passengers yearly, and cost about twenty million dollars. The five main spans are together three thousand seven hundred and twenty-four feet long and weigh about eighty-six million pounds. They are ninety feet wide and one hundred and thirty-five feet high above the water. One span of six hundred and thirty feet crosses the full width of Blackwells Island and is flanked by one-thousand-one-hundred-and-eighty-two-foot and nine-hundred-and-eighty-four-foot cantilever channel spans simultaneously built out from it, and both shores without any supporting falsework. Some of the separate pieces are over one hundred feet long and weigh one hundred and

twenty tons each. The enormous main posts, one hundred and eighty-five feet high, are composed of several sections riveted together in place, and, notwithstanding their huge rigid masses, were, after erection, deliberately bent several inches out of line at the top, to permit the connection of other members before the steel bars and struts had been extended and compressed by the weight of the structure itself to the final lengths for which they were computed.

The weight of the island and shore spans was too great to be supported on wooden falsework, so more than four million pounds of steel columns and girders of a quality fully equal to first-class railroad viaducts, were manufactured and placed solely to form a scaffold on which they were erected, and which was afterwards removed and cut up. Steel derricks with booms eighty-five feet long, capable of lifting seventy tons, were a very important factor in the erection, and two Z-shaped steel towers one hundred and twenty-four feet high, weighing about six hundred and twenty-five tons each, were moved out on the cantilever arms, overhanging the finished work far enough for their tackles and hoisting engines to build out another panel in advance, and so on.

The Manhattan Bridge, completed across the East River in 1910, has a main suspended span of one thousand four hundred and seventy feet, has eight lines of railroad tracks, two promenades, and one wide driveway, together estimated to carry a maximum moving load of sixteen thousand pounds per foot of bridge length. With its approaches it has cost about twenty-five million dollars. Its main piers have foundations built under heavy air pressure on the solid rock far below the surface of the river. On them are steel towers, about three hundred feet high, which weigh twelve million five hundred thou-

sand pounds each, and are the slenderest in proportion to their height of all bridge towers, being designed for the massive riveted columns twelve and a half feet wide at the base, to spring back and forth about two feet with changes of temperature and loading.

The towers were erected by curious steel travelers carrying powerful derricks and hoisting engines that were clamped to the towers and hoisted themselves up as fast as the tower progressed. The towers support the four fifteen-hundred-ton steel cables from which the floor platforms and trusses are suspended. The cables, each made of nine thousand four hundred and seventy-two straight wires, were built up in place from a suspension-bridge working platform supported on sixteen heavy twisted steel ropes that were first carried across the river and dropped on the bottom, then hoisted to the tops of the towers, while the river was patrolled to stop all navigation.

Above each cable an endless steel rope was stretched across the river and driven like a belt to pull back and forth two pulleys moving simultaneously in opposite directions and each carrying a loop of cable wire. These loops were adjusted to exact curve, length, and strain, and were attached to the anchorages at each end exactly like continuous skeins of yarn, which were afterwards gathered into strands and compacted under heavy pressure into solid cylinders twenty-one inches in diameter protected by wire wrapping wound on by electric machines. After the completion of the main cables it was a comparatively easy matter to suspend the main floor from them, and on it to operate a number of movable steel derricks back and forth from the ends to the middle to complete the erection of the trusses, bracing, and other parts.

With one exception, no bridge in the world has a span

both as high and as long as the five-hundred-foot double-track railroad arch four hundred feet above the Zambesi River near Victoria Falls in equatorial Africa, which was completed in 1905. A line attached to a rocket was shot across the impassable gorge; with it a rope was hauled across, and then a steel cable installed on which a ten-ton trolley carried half the steel for the span to the bank opposite the railroad terminus. Horse-shoe-shape tunnels were cut in the solid rock of both banks, and in them many loops of steel rope were secured to act as anchorages, which supported during erection the semi-arch trusses built out simultaneously from both sides, as cantilevers, much in the same manner as the Niagara bridges, except that all the materials were handled by the cableway trolley. On account of the great height a precaution, seldom or never before used, was taken by the suspension of a net under the bridge to catch the workmen in case of accident. It did not meet with favor and was abandoned.

Several of the largest and finest railroad bridges are those which have long and lofty spans over the Missouri and Ohio rivers, where floods of fifty feet in height may occur in a few days, and not only sweep away all obstructions with their swift current and great masses of débris, but undermine piers and falsework and tear down permanent and temporary structures exposed to their fury. As it takes weeks or months to erect a great span under the most favorable circumstances, and as the floods can not be foretold, many great bridges over these rivers have suffered severely, and in some cases have been wrecked twice before completion.

No bridge erection was ever more difficult and perilous than that of the bridge across the Copper River, Alaska, between the vast Miles and Childs glaciers,

three miles wide and three hundred feet deep, which move with great rapidity and as they break off drop millions of tons of ice into the river, making a continuous thunder, creating high tidal waves, and filling the great torrential stream with large icebergs.

In the arctic winter, between the active glacial seasons, holes were cut through the seven-foot ice, foundations were carried in pneumatic caissons to rock, and enormous concrete piers with steel armor to protect them from the ice were built, one of them on an artificial island previously constructed to shoal the water and fend off the deep-draft icebergs.

Piles were driven through the ice, and supported timber falsework, on which the four great spans were erected with the utmost haste. When the longest span was half finished a flood lifted the ice ten feet and displaced bridge and falsework without destroying them. The steelwork was readjusted, the ice thawed away from the piles with steam pipes, and the work resumed with desperate haste, while the river rapidly rose thirty feet behind an ice dam which had formed just above the bridge and threatened to break at any moment. The last pin had been driven and the last wedge loosened scarcely an hour, and the men barely had time to get ashore, when the dam broke and the water swept away the falsework, leaving the bridge unharmed high above the flood.

No bridge span has ever been built so long as the one-thousand-eight-hundred-foot span of the double-track, double-trolley Quebec bridge across the St. Lawrence River, which had trusses three hundred and fifteen feet deep, was one hundred and fifty feet high above water two hundred feet deep, with its shore spans was two thousand eight hundred feet long between anchorages,

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and weighed over eighty million pounds. Its piers were sunk through enormous bowlders, far below the bottom of the river, in a swift current subject to sixteen-foot tides. One five-hundred-foot shore span weighing about fourteen million pounds was erected on temporary steel towers over one hundred feet high, which weighed over one thousand two hundred tons.

From the shore span as an anchor it was intended to build out one half (nine hundred feet) of the great main span as a cantilever one hundred and fifty feet above the water, and then leave it two years until the other half of the bridge could be similarly built from the other shore to meet it. Most of the first cantilever was thus erected by a four hundred and fifty ton steel traveler two hundred and fifteen feet high, which advanced on heavy temporary girders provided outside the trusses and shifted forward as the traveler advanced. The traveler was equipped with twenty-four tackles, rigged with thirty-one miles of ropes, and operated by immense electric engines capable of hoisting and maintaining two one-hundred-ton pieces simultaneously.

The work had been in progress about five years, over seventeen thousand tons of steel had been erected with a force of about two hundred men, and no accidents had occurred except from falls due to the carelessness of the individuals hurt. Just before the close of the working day, August 29, 1907, the whole erected superstructure collapsed and seventy-five of the eighty-six men at work on it were killed. One man fell four hundred feet into the river and escaped alive, and two others, working inside great riveted columns, which were smashed on the rocks below, survived the fall of over one hundred feet.

Of the seventeen thousand tons of wrecked steel,

nearly half fell into water from one hundred to two hundred feet in depth, where it will forever remain undisturbed, a fitting mausoleum for its victims. The remainder fell on shore, above low-tide level, and was so inextricably twisted, interlocked, crushed, and mangled that it appeared a hopeless task to detach the long and massive pieces, most of them bolted or riveted together. The task was, however, undertaken early in 1910, and was more than half completed during that year. Sticks of dynamite end to end, making continuous lines attached to a rod or a cord or even inserted in a piece of small hose, were secured at low tide to column or girder, and when submerged by high tide were fired. They cut the massive pieces in two very cheaply and effectively, although at the expense of considerable risk from flying pieces, which were thrown thousands of feet.

In many cases very large and heavy pieces were rapidly cut by the oxyacetylene torch. This consisted of two small brass tubes, each with a hose connection, valve, and a nozzle with an opening no larger than a fine needle, through which acetylene and oxygen gases were successively played. The former when ignited heated the steel immediately to a temperature of over six thousand degrees, after which it was cut off, and the oxygen being played on the white-hot metal, rapidly burned a narrow slot, like a smooth sawcut, through it at the rate of about ten square inches per minute. In this way the pieces were reduced to a convenient size to be removed by derricks. Designs have been made for a much wider and heavier bridge on the same site, and work has already been started on its foundations, since the old ones, although entirely uninjured by the collapse, were not adequate for the new structure.

The very long spans, which involve such difficult and

interesting methods of construction, form but the smallest part of the steel bridges annually erected. A larger proportion is included in the long viaducts of short spans up to ninety feet long, supported on steel towers up to three hundred feet high, which carry roads over wide and deep valleys. These are usually made with two or four lines of simple solid girders weighing ten to forty tons each, which are handled either by derricks with very long and powerful booms moving on top of the completed structure and erecting one tower and span in advance, or by steel travelers with long cantilever trusses projecting in front from which tackles are suspended to handle and support the steel work until it is assembled. connected, and self-sustaining.

Sometimes the great tackles swing the heavy pieces, pendulum-wise, from one to another and lower them to place; sometimes the steel is brought under the traveler and carried out on the cantilever by trolleys traversing it from end to end, and sometimes the cantilever trusses themselves swing in great horizontal arcs. Sometimes, when the spans are not too long, the work is done by derrick cars, which bring the steel from a storage yard on shore and erect it at one operation, or receive it in mid-span from the cars on which it is shipped from the bridge shops.

In the case of the famous Kinzua Viaduct, long known as the highest in the world, the slender original structure was built by light derricks carried forward on the steelwork itself as it was erected; but when it was recently replaced by a much heavier structure on the same foundations, a rolling bridge long enough to reach from one tower to the second one in advance was moved from end to end of the viaduct with trolleys and tackles suspended from it, by which one old span and one tower

were removed and new ones built in each successive position as it advanced.

The rebuilding of a lofty viaduct without falsework, while in service, is one of the most difficult and dangerous of the bridge erectors' problems, and was formerly considered almost impossible, but has lately been successfully accomplished in several bridges, including those across the Hudson River at Poughkeepsie and at Rondout.

Among the most recent or interesting of steel viaducts are the Tinkers Creek Viaduct, one thousand three hundred feet long and one hundred and sixty-one feet high, erected by trolley hoists on pivoted cantilever trusses two hundred feet long; the Stony Brook Glen Viaduct, two hundred and forty-two feet high, erected by an overhead traveler with a swinging boom truss one hundred and twenty-five feet long; the ten-thousand-ton approach of the Queensboro Bridge, New York, with massive six-track, double-deck spans one hundred and sixty-six feet long and over one hundred feet above the ground, erected by a five-hundred-ton wooden tower traveler one hundred and thirty-seven feet high, which moved on the ground astride the viaduct; and some of the New York Elevated Railroad structure erected by overhead traveling derricks which completed one thousand tons of steel work about one-fifth mile of viaduct a day.

American engineers and contractors have also built the Lethbridge Viaduct, three hundred and fourteen feet high. This is in Canada, and some of the most dangerous work was done by men in huge steel cages suspended from the overhead steel cantilever traveler. The Gokteik Viaduct, in the Himalaya Mountains, Burmah, three thousand two hundred and sixty feet long and three hundred and twenty feet high, was fabricated in Harrisburg, and was erected without accident, in ten months, by thirty-five

bridge men and five hundred natives using an overhead steel cantilever traveler of the unprecedented length of two hundred and ninety feet. Much simpler was the erection by Americans of a number of light viaducts on the Uganda Railroad, in equatorial Africa, with a steel traveler consisting of a light tower running on the completed structure and allowing the steel to be passed through its base to derrick booms which erected it in advance. One day the men, riding from camp to the bridge site on the locomotive, shot a lioness as she was stalking a zebra. On several occasions their vegetable garden was destroyed by rhinoceroses, and on sections of their railroad only a few miles from their camps, many men were devoured by lions, who even dragged them from the sleeping car and from a hospital bed, leaping with the victim over a high palisade.

By far the greatest proportion of all bridge work consists of short and moderate length spans erected on falsework and handled by ordinary methods. This involves chiefly routine work done with standard methods and equipment, the latter noticeable for its great efficiency and large capacity and for the application of steam, compressed air, and electric power for almost all operations, eliminating a great part of hand labor on important work.

When it is realized that there are annually fabricated and erected about five hundred thousand tons of steel bridges in the United States alone, and that the few examples here noted do not begin to illustrate all the methods of erection, or include one per cent of the total amount of bridge work, it is easy to see why bridge construction has become a specialized calling. At the present time, the men who rear our great bridges are, for the most part, men who have been trained in this partic-

ular occupation, and who in many cases follow no other. They, as well as the men who design the structures, are entitled to high rank as engineers. The leaders are endowed with great professional skill, are quick to plan new methods for difficult cases, and are able to execute delicate and critical operations under perilous and harassing circumstances. They have vast responsibilities, with the possibility of great losses and disasters if they fail, and comparatively little reward except the satisfaction of well-doing when they succeed.

MORSE AND THE INVENTION OF THE TELEGRAPH[1]

By PHILIP G. HUBERT, Jr.

ON board the ship "Sully," in which Samuel Finley Breese Morse sailed from Havre to New York in the autumn of 1832, the recent discovery in France of the means of obtaining an electric spark from a magnet was a favorite topic of conversation among the passengers, and it was during the voyage that Morse conceived the idea of an electromagnetic and chemical recording telegraph. Before he reached New York he had made drawings and specifications of his conception, which he exhibited to his fellow passengers.

Few great inventions that have made their authors immortal were so completely grasped at inception as this. Morse was accustomed to keep small notebooks in which to make records of his work, and scores of these books are still in existence. As he sat upon the deck of the "Sully," one night after dinner, he drew from his pocket one of these books and began to make marks to represent letters and figures to be produced by electricity at a distance.

The mechanism by which the results were to be reached was wrought out by slow and laborious thought, but the vision as a whole was clear. The current of electricity passed instantaneously to any distance along a wire, but the current being interrupted, a spark appeared. This spark represented one sign; its absence another; the time of its absence still another. Here are three signs to be

[1] From "Inventions and Inventors," by courtesy of the author and Charles Scribner's Sons. Copyright, 1893.

combined into the representation of figures or letters. They can be made to form an alphabet. Words may thus be indicated. A telegraph, an instrument to record at a distance, will result. Continents shall be crossed. This great and wide sea shall be no barrier. "If it will go ten miles without stopping," he said, "I can make it go around the globe."

He worked incessantly all that next day and could not sleep at night in his berth. In a few days he submitted some rough drafts of his invention to William C. Rives, of Virginia, who was returning from Paris, where he had been minister of the United States. Mr. Rives suggested various difficulties, over which Morse spent several sleepless nights, announcing in the morning at breakfast table the new devices by which he proposed to accomplish the task before him. He exhibited a drawing of the instrument which he said would do the work, and so completely had he mastered all the details that five years afterward, when a model of this instrument was constructed, it was instantly recognized as the one he had devised and drawn in his sketchbook and exhibited to his fellow passengers on the ship. In view of subsequent claims made by a fellow passenger to the honor of having suggested the telegraph, these details are interesting and important.

Circumstances delayed the construction of a recording telegraph by Morse, but the subject slumbered in his mind. During his absence abroad he had been elected professor of the literature of the arts of design, in the University of the City of New York, and this work occupied his attention for some time. Three years afterward, in November, 1835, he completed a rude telegraph instrument — the first recording apparatus; but it embodied the mechanical principle now in use the world over.

His whole plan was not completed until July, 1837, when

by means of two instruments he was able to communicate from as well as to a distant point. In September hundreds of people saw the new instrument in operation at the university, most of whom looked upon it as a scientific toy constructed by an unfortunate dreamer. The following year the invention was sufficiently perfected to enable Morse to direct the attention of Congress to it and ask its aid in the construction of an experimental line between Washington and Baltimore.

Late in the long session of 1838 he appeared before that body with his instrument. Before leaving New York with it he had invited a few friends to see it work. Now began in the life of Morse a period of years during which his whole time was devoted to convincing the world, first, that his electric telegraph would really communicate messages, and secondly, that if it worked at all, it was of great practical value. Strange to say that this required any argument at all. But that in those days it did may be inferred from the fact that Morse could then find no help far or near. His invention was regarded as interesting, but of no importance, either scientifically or commercially. In Washington, where he first went, he found so little encouragement that he went to Europe with the hope of drawing the attention of foreign governments to the advantages of the invention, and of securing patents on it; he had filed a caveat at the Patent Office in this country. His mission was a failure. England refused him a patent, and France gave him only a useless paper which assured for him no special privileges. He returned home disappointed but not discouraged, and waited four years longer before he again attempted to interest Congress in his invention.

This extraordinary struggle lasted twelve years, during which, with his mind absorbed in one idea and yet almost wholly dependent for bread upon his profession as an art-

ist, it was impossible to pursue art with the enthusiasm and industry essential to success.

His situation was forlorn in the extreme. The father of three little children, now motherless, his pecuniary means exhausted by his residence in Europe, and unable to pursue art without sacrificing his invention, he was at his wits' end. He had visions of usefulness by the invention of a telegraph that should bring the continents of the earth into intercourse. He was poor and knew that wealth as well as fame was within his reach. He had long received assistance from his father and brothers when his profession did not supply the needed means of support for himself and family; but it seemed like robbery to take the money of others for experiments, the success of which he could not expect them to believe in until he could give practical evidence that the instrument would do the work proposed.

It was the old story of genius contending with poverty. His brothers comforted, encouraged, and cheered him. In the house of his brother Richard he found a home and the tender care that he required. Sidney, the other brother, also helped him. On the corner of Nassau and Beekman Streets, now the site of the handsome Morse Building, his brothers erected a building where were the offices of the newspaper of which they were the editors and proprietors. In the fifth story of this building a room was assigned to him which was for several years his studio, bedroom, parlor, kitchen, and workshop. On one side of the room stood a little cot on which he slept in the brief hours which he allowed himself for repose.

On the other side stood his lathe with which the inventor turned the brass apparatus necessary in the construction of his instruments. He had, with his own hands, first whittled the model; then he made the molds for the cast-

ings. Here were brought to him, day by day, crackers and the simplest food, by which, with tea prepared by himself, he sustained life while he toiled incessantly to give being to the idea that possessed him.

Before leaving for Europe he had suffered a great disappointment as an artist. The government had offered to American artists, to be selected by a committee of Congress, commissions to paint pictures for the panels in the rotunda of the Capitol. Morse was anxious to be employed upon one or more of them. He was the president of the National Academy of Design, and there was an eminent fitness in calling him to this national work. Allston urged the appointment of Morse. John Quincy Adams, then a member of the House and on the committee to whom this subject was referred, submitted a resolution in the House that foreign artists be allowed to compete for these commissions, and in support alleged that there were no American artists competent to execute the paintings. This gave great and just offense to the artists and the public. A severe reply to Adams appeared in the New York "Evening Post." It was written by James Fenimore Cooper, but it was attributed to Morse, whose pen was well known to be skillful, and in consequence his name was rejected by the committee. He never recovered fully from the effects of that blow. Forty years afterward he could not speak of it without emotion. He had consecrated years of his life to the preparation for just such work.

It was well for him and for his country and the world that the artist in Morse was disappointed. From painter he became inventor, and from that time until the world acknowledged the greatness and importance of his invention he turned not back. His appointment as professor in the City University entitled him to certain rooms in

the University Building looking out upon Washington Square, and here the first working models of the telegraph were brought into existence.

"There," he says, "I immediately commenced, with very limited, means, to experiment upon my invention. My first instrument was made up of an old picture or canvas frame fastened to a table; the wheels of an old wooden clock, moved by a weight to carry the paper forward; three wooden drums, upon one of which the paper was wound and passed over the other two; a wooden pendulum suspended to the top piece of the picture or stretching frame and vibrating across the paper as it passes over the center wooden drum; a pencil at the lower end of the pendulum, in contact with the paper; an electromagnet fastened to a shelf across the picture or stretching frame, opposite to an armature made fast to the pendulum; a type rule and type for breaking the circuit, resting on an endless band, composed of carpet binding, which passed over two wooden rollers moved by a wooden crank.

"Up to the autumn of 1837 my telegraphic apparatus existed in so rude a form that I felt a reluctance to have it seen. My means were very limited — so limited as to preclude the possibility of constructing an apparatus of such mechanical finish as to warrant my success in venturing upon its public exhibition. I had no wish to expose to ridicule the representative of so many hours of laborious thought.

"Prior to the summer of 1837, at which time Mr. Alfred Vail's attention became attracted to my telegraph, I depended upon my pencil for subsistence. Indeed, so straitened were my circumstances that, in order to save time to carry out my invention and to economize my scanty means, I had for many months lodged and eaten in my studio,

procuring my food in small quantities from some grocery and preparing it myself. To conceal from my friends the stinted manner in which I lived, I was in the habit of bringing my food to my room in the evenings, and this was my mode of life for many years."

Before the telegraph was actually tried and practiced the cumbersome piano-key board devised by Morse in his first experiments was done away with and the simple device of a single key, with which we are all familiar, was adopted. Meantime Morse was practically abandoning art. His friends among the profession had subscribed three thousand dollars in order to enable him to paint the picture he had in mind when he applied for the government work at Washington, "The Signing of the First Compact on Board the Mayflower," and he undertook the commission in 1838, only to give it up in 1841 and to return to the subscribers the amount paid with interest.

While Morse had been in Paris, in 1839, he had heard of Daguerre, who had discovered the method of fixing the image of the camera, which feat was then creating a great sensation among scientific men. Professor Morse was anxious to see the results of this discovery before leaving Paris, and the American consul, Robert Walsh, arranged an interview between the two inventors. Daguerre promised to send Morse a copy of the descriptive publication which he intended to make as soon as a pension he expected from the French Government for the disclosure of his discovery should be secured. He kept his promise, and Morse was probably the first recipient of the pamphlet in this country.

From the drawings it contained he constructed the first photographic apparatus made in the United States, and from a back window in the University Building he obtained a good representation of the tower of the Church of the

Messiah on Broadway. This possesses an historical interest as being the first photograph in America. It was on a plate the size of a playing card. With Professor J. W. Draper, in a studio built on the roof of the university, he succeeded in taking likenesses of the living human face. His subjects were compelled to sit fifteen minutes in the bright sunlight, with their eyes closed, of course. Professor Draper shortened the process and was the first to take portraits with the eyes open.

At the session of Congress of 1842–1843 Morse again appeared with his telegraph, and on February 21, 1843, John P. Kennedy, of Maryland, moved that a bill appropriating thirty thousand dollars to be expended, under the direction of the Secretary of the Treasury, in a series of experiments for testing the merits of the telegraph, should be considered. The proposal met with ridicule. Johnson, of Tennessee, moved, as an amendment, that one-half should be given to a lecturer on mesmerism, then in Washington, to try mesmeric experiments under the direction of the Secretary of the Treasury; and Mr. Houston said that Millerism ought to be included in the benefits of the appropriation.

After the indulgence of much cheap wit, Mr. Mason, of Ohio, protested against such frivolity as injurious to the character of the House and asked the chair to rule the amendments out of order. The chair (John White, of Kentucky) ruled the amendments in order because "it would require a scientific analysis to determine how far the magnetism of the mesmerism was analogous to that to be employed in telegraphy."

This wit was applauded with peals of laughter, but the amendment was voted down and the bill passed the House on February 23d by the close vote of eighty-nine to eighty-three. In the Senate the bill met with neither sneers nor

opposition, but its progress was discouragingly slow. At twilight on the last evening of the session (March 3, 1842) there were one hundred and nineteen bills before it. It seemed impossible for it to be reached in regular course before the hour of adjournment should arrive, and Morse, who had anxiously watched the dreary course of business all day from the gallery of the Senate chamber, went with a sad heart to his hotel and prepared to leave for New York at an early hour the next morning. His cup of disappointment seemed to be about full. With the exception of Alfred Vail, a young student in the University, through whose influence some money had been subscribed in return for a one-fourth interest in the invention, and of Professor L. D. Gale, who had shown much interest in the work, and was also a partner in the enterprise, Morse knew of no one who seemed to believe enough in him and his telegraph to advance another dollar.

As he came down to breakfast the next morning a young lady entered and came forward with a smile, exclaiming, "I have come to congratulate you."

"Upon what?" inquired the professor.

"Upon the passage of your bill," she replied.

"Impossible! Its fate was sealed last evening. You must be mistaken."

"Not at all," answered the young lady, the daughter of Morse's friend, the Commissioner of Patents, H. L. Ellsworth; "father sent me to tell you that your bill was passed. He remained until the session closed, and yours was the last bill but one acted upon, and it was passed just five minutes before the adjournment. And I am so glad to be able to be the first one to tell you. Mother says you must come home with me to breakfast."

Morse, overcome by the intelligence, promised that his young friend, the bearer of these good tidings, should

send the first message over the first line of telegraph that was opened.

He writes to Alfred Vail that day: "The amount of business before the Senate rendered it more and more doubtful, as the session drew to a close, whether the House bill on the telegraph would be reached, and on the last day, March 3, 1843, I was advised by one of my senatorial friends to make up my mind for failure, as he deemed it next to impossible that it could be reached before the adjournment. The bill, however, was reached a few minutes before midnight and passed. This was the turning point in the history of the telegraph. My personal funds were reduced to the fraction of a dollar, and, had the passage of the bill failed from any cause, there would have been little prospect of another attempt on my part to introduce to the world my new invention."

The appropriation by Congress having been made, Morse went to work with energy and delight to construct the first line of his electric telegraph. It was important that it should be laid where it would attract the attention of the government, and this consideration decided the question in favor of a line between Washington and Baltimore. He had as assistants Professor Gale and Professor J. C. Fisher. Mr. Vail was to devote his attention to making the instruments and the purchase of materials.

Morse himself was general superintendent under the appointment of the government, and gave attention to the minutest details. All disbursements passed through his hands. In point of accuracy, the preservation of vouchers and presentation of accounts, General Washington himself was not more precise, lucid, and correct. Ezra Cornell, afterward one of the most successful constructors of telegraph lines, was employed to take charge of

the work under Morse. Much time and expense were lost in consequence of following a plan for laying the wires in a leaden tube, and it was only when it was decided to string them on posts that work began to proceed rapidly.

In expectation of the meeting of the National Whig Convention, May 1, 1844, to nominate candidates for president and vice-president, energy was redoubled, and by that time the wires were in working order twenty-two miles from Washington, toward Baltimore. The day before the convention met, Professor Morse wrote to Vail that certain signals should mean the nomination of a particular candidate. The experiment was approaching its crisis. The convention assembled and Henry Clay was nominated by acclamation to the presidency. The news was conveyed on the railroad to the point reached by the telegraph and thence instantly transmitted over the wires to Washington. An hour afterward passengers arriving at the capital, and supposing that they had brought the first intelligence, were surprised to find that the announcement had been made already and that they were the bearers of old news. The convention shortly afterward nominated Frelinghuysen as vice-president, and the intelligence was sent to Washington in the same manner. Public astonishment was great, and many persons doubted that the feat could have been performed. Before May had elapsed the line reached Baltimore.

On the 24th of May, 1844, Morse was prepared to put to final test the great experiment on which his mind had been laboring for twelve anxious years. Vail, his assistant, was at the Baltimore terminus. Morse had invited his friends to assemble in the chamber of the United States Supreme Court, where he had his instrument, from which the wires extended to Baltimore. He had promised his

young friend, Miss Ellsworth, that she should send the first message over the wires. Her mother suggested the familiar words of scripture (Numbers, xxiii. 23), "What hath God wrought!" The words were chosen without consultation with the inventor, but were singularly the expression of his own sentiment and his own experience in bringing his work to successful accomplishment. Perfectly religious in his convictions, and trained from earliest childhood to believe in the special superintendence of Providence in the minutest affairs of man, he had acted throughout the whole of his struggles under the firm persuasion that God was working in him to do His own pleasure in this thing.

Perhaps the most painful chapter of Morse's life is the history of the lawsuits in which he was involved in defense of his rights. His reputation as well as his property were assailed. Exceedingly sensitive to these attacks, the suits that followed the success of the telegraph cost him inexpressible distress. It is some satisfaction to be able to record that after years of bitter controversy the final decision was favorable to the inventor.

Honors began to pour in upon him from even the uttermost parts of the earth. The Sultan of Turkey was the first monarch to acknowledge Morse as a public benefactor. This was in 1848. The kings of Prussia and Würtemburg, and the Emperor of Austria each gave him a gold medal, that of the first named being set in a massive gold snuff box. In 1856 the Emperor of the French made him a chevalier of the Legion of Honor. Orders from Denmark, Spain, Italy, Portugal soon followed. In 1858 a special congress was called by the Emperor of the French to devise a suitable testimonial of the nation to Professor Morse. Representatives from ten sovereignties convened at Paris, and by a unanimous vote gave, in the aggregate, eighty

thousand dollars as an honorary gratuity to Professor Morse. The states participating in this testimonial were France, Austria, Russia, Belgium, Holland, Sweden, Piedmont, the Holy See, Tuscany and Turkey.

Professor Morse was one of the first to suggest, and the first to carry out, the use of a marine cable. During the summer of 1842 he had been making elaborate preparations for an experiment destined to give wonderful development to his invention. This was no less than a submarine wire, to demonstrate the fact that the current of electricity could be conducted as well under water as through the air. Of this he had entertained no doubt. "If I can make it work ten miles, I can make it go around the globe," was a favorite expression of his in the infancy of his enterprise. But he wished to prove it. He insulated his wire as well as he could with hempen strands well covered with pitch, tar, and india-rubber. In the course of the autumn he was prepared to put the question to the test of actual experiment. The wire was only the twelfth of an inch in diameter. About two miles of this, wound on a reel, was placed in a small rowboat, and with one man at the oars and Professor Morse at the stern, the work of paying out the cable was begun.

It was a beautiful moonlight night, and those who had prolonged their evening rambles on the Battery must have wondered, as they watched the proceedings in the boat, what kind of fishing the two men could be engaged in that required so long a line. In somewhat less than two hours, on that eventful evening of October 18, 1842, the first cable was laid. Professor Morse returned to his lodgings and waited with some anxiety the time when he should be able to test the experiment fully and fairly. The next morning the New York "Herald" contained the following editorial announcement:

Morse's Electromagnetic Telegraph

"This important invention is to be exhibited in operation at Castle Garden, between the hours of twelve and one o'clock to-day. One telegraph will be erected on Governor's Island and one at the Castle, and messages will be interchanged and orders transmitted during the day. Many have been incredulous as to the powers of this wonderful triumph of science and art. All such may now have an opportunity of fairly testing it. It is destined to work a complete revolution in the mode of transmitting intelligence throughout the civilized world."

At daybreak the professor was on the Battery, and had just demonstrated his success by the transmission of three or four characters between the termini of the line, when the communication was suddenly interrupted, and it was found impossible to send any messages through the conductor. The cause of this was evident when he observed no less than seven vessels lying along the line of the submerged cable, one of which, in getting under way, had raised it on her anchor. The sailors, unable to divine its meaning, hauled in about two hundred feet of it on deck, and finding no end, cut off that portion and carried it away with them. Thus ended the first attempt at submarine telegraphing. The crowd that had assembled on the Battery dispersed with jeers, most of them believing they had been made the victim of a hoax.

In a letter to John C. Spencer, then Secretary of the Treasury, in August, 1843, concerning electromagnetism and its powers, he wrote:

"The practical inference from this law is that a telegraphic communication on the electro-magnetic plan may with certainty be established across the Altantic

Ocean. Startling as this may now seem, I am confident the time will come when this project will be realized."

In 1871 a statue of Professor Morse was erected in Central Park, New York, at the expense of the telegraph operators of the country. It was unveiled on June 10 with imposing ceremonies. There were delegates from every State in the Union, and from the British provinces. In the evening a public reception was given to the venerable inventor at the Academy of Music, at which William Orton, president of the Western Union Telegraph Company, presided, assisted by scores of the leading public men of the country as vice-presidents. The last scene was an impressive one. It was announced that the telegraphic instrument before the audience was then in connection with every other one of the ten thousand instruments in America. Then Miss Cornell, a young telegraphic operator, sent this message from the key: "Greeting and thanks to the telegraph fraternity throughout the world. Glory to God in the highest, on earth peace, good-will to men." The venerable inventor, the personification of simplicity, dignity, and kindliness, was then conducted to the instrument, and touching the key, sent out: "S. F. B. Morse." A storm of enthusiasm swept through the house as the audience rose, the ladies waving their handkerchiefs and the men cheering.

Professor Morse last appeared in public on February 22, 1872, when he unveiled the statue of Franklin, erected in Printinghouse Square, in New York. He died, after a short illness, on April 2, 1872, and was buried in Greenwood Cemetery. On the day of the funeral, April 5th, every telegraph office in the country was draped in mourning.

THE DRAMATIC BIRTH OF THE TELEPHONE[1]

By THOMAS A. WATSON

IT was my good fortune to be associated with Alexander Graham Bell as mechanician during the whole of the famous experiments by which the telephone was developed from a crude and imperfect instrument into a commercial success. I was employed by him to embody in practical form his ideas: I constructed all the early telephones, assisted in all the tests of the apparatus, and heard the first word ever transmitted by an electric speaking telephone.

Nearly a year before his first experiment on the speaking telephone was made, Mr. Bell was developing an invention that he called the "Harmonic" telegraph. This was an improvement on the Morse system. It aimed to utilize the well-known law of sympathetic vibration, in order to transmit simultaneously and without confusion several Morse dot-and-dash messages over a single wire. My intimacy with him and my first knowledge of his idea of the speaking telephone date from these telegraph experiments in the early seventies. I vividly remember when he first told me he was convinced that the telegraphing of speech was a possibility, and explained to me his theoretical conception of the principle on which the development of that idea must depend, — a conception since proved correct. His theory was, that the transmission of articulate speech over a telegraph wire would be possible if he could make an electric current vary in intensity

[1] Especially written for "Vocations."

precisely as the air varies in its density while a sound is passing through it.

This theoretical current he called "undulatory," to distinguish it from a rapid make-and-break or intermittent current. That an apparatus which would do this was possible he had no doubt. In fact, he had already sketched and described a complicated instrument of the kind but had not sufficient confidence that it would operate practically to risk the rather large expenditure needed for its construction, and, impelled to devote himself to electrical matters, he was working on the details of his "Harmonic" Telegraph, an invention altogether different from the speaking telephone, but of interest here as having accidentally led to the discovery that his theoretical conception of a telephone was capable of embodiment in a working instrument.

A description of the apparatus used in the harmonic telegraph experiments is necessary to an understanding of this important discovery.

As has been stated, Mr. Bell's harmonic telegraph is based on the law of sympathetic vibration. This law may be illustrated by singing a note into a piano with the sustaining pedal depressed. The string that is tuned to the pitch of the uttered sound will then be set into strong vibration, while the rest of the strings will be quite silent. If two or more notes are sounded simultaneously the corresponding strings only will resound, each selecting its own vibrations from the air.

This can be done electrically and from a distance by placing an electromagnet under several of the piano strings, connecting the magnets in a circuit with an electric battery. If by an interrupter the electric current be made and broken the number of times per second that corresponds to the rate of vibration of one of the strings, only

the string that naturally vibrates at this rate will respond, the others will remain silent. The difference in these two experiments is that in the first case the rhythmic impulses that set the string into vibration were conveyed directly through the air, while in the second case they acted through the wire and the electromagnets.

If two or more sets of these current interruptions be made simultaneously, each set of electric makes-and-breaks will cause only its corresponding string to vibrate so that it would be possible to send several messages simultaneously by using a differently pitched interrupter for each message.

In the apparatus used by Mr. Bell, instead of the stretched strings of a piano, he used flat strips of springy steel tuned to different pitches, by varying their lengths. Each spring was clamped by one end to a pole of an electromagnet, and its free end projected over the other pole.

His transmitters or current interrupters were similar, but in these each spring was kept in constant vibration by a magnet. A metal point was placed above each spring so that the latter would touch it at every vibration and make and break the electric current the number of times per second that corresponded to the pitch of the string. By tuning the springs of the receivers to accord with those of the transmitters and connecting both receivers and transmitters to the line wire with proper signaling keys and a battery, as many messages as there were different pitches could be transmitted simultaneously, each receiver responding only when the electric pulsations passing through it corresponded to the pitch of its spring.

Theoretically this system is quite simple and ought to work pretty well, and it has, I believe, been recently perfected and made of practical use, but at the time of which I speak, it was far from perfect and worked very irregu-

larly. To overcome its imperfections, Mr. Bell had engaged my services and was himself devoting to it all the time he could spare from his work as Professor of Vocal Physiology at the Boston University.

The rooms in which the experiments were carried on were in the attic of the building, 109 Court Street, Boston, used at that time for manufacturing purposes, now used, for a Dime Museum. Our improvised telegraph wire was hung up on the rafters and ran from one room to the other.

On the afternoon of June 2, 1875, I was helping Mr. Bell test some improvement that he had made in his harmonic telegraph apparatus. The transmitters were in the room where I was stationed and the corresponding receivers were in Mr. Bell's room. The afternoon was very hot and the baking atmosphere of those attic rooms was not conducive to energetic work. The apparatus, also, seemed to feel the effect of the weather. It had never been more perverse. The transmitters would not buzz and the receivers would not respond. Instead of answering sharply and distinctly to the signals I was sending from the transmitters, the springs of the receivers would stick to their magnets and remain silent.

This had often happened before, but we had always tinkered and tested until we had remedied the trouble, and then we had gone plodding on toward the very prosaic goal we had set up of an improvement in the Morse telegraph. This afternoon none of the usual remedies would work and we were pretty nearly in despair.

But the Fates were really working for us, and that time of weariness and discouragement was the darkness before the dawn. Bell's idea of a "current of electricity which should vary in intensity as the air varies in density during the production of a sound" was nearing its practical realization. The events of that afternoon were destined to

deprive the harmonic telegraph of all its interest to us except as a stepping-stone to a far greater invention.

Mr. Bell, in an endeavor to improve the working of the receivers, was retuning one of their springs. To ascertain if the pitch was correct he had pressed it against his ear and was listening to the faint sound of the intermittent current passing through the magnet — a sound which could always be heard in that way whether the spring was correctly tuned or not. While he was doing this the spring of the instrument in my room, for some reason, stopped vibrating, and as usual I snapped it with my finger to start it. At once a shout came from the other room and Mr. Bell rushed out inquiring what I had done. I explained. "Do it again!" said he, and while he listened I snapped springs during the rest of that afternoon and so late into the night that the janitor, forgetting us, locked us in.

What had happened? Simply this. The spring that I had plucked had become permanently magnetized by long use in close proximity to its magnet and when I snapped it, it became a little dynamo and generated by its vibration an electric current that realized Bell's ideal. When this current passed through the magnet of the receiver at Mr. Bell's ear, it set into vibration the spring of that instrument, which, being confined against his ear, was in a condition to vibrate as a diaphragm and not merely as a free reed. He, a trained acoustician, at once perceived that, instead of the harsh nasal whine of the intermittent current, — much like the cry of a cicada on a hot summer day, — he was hearing very faintly the peculiar soft twang of the identical spring I was plucking, and he recognized instantly that the electric current carrying to him such a sound was realizing his long-cherished idea of an "undulatory" current varying in intensity exactly as

the air was varying in density about my vibrating spring. Here was the instrument that he had so long sought, for he knew that an apparatus that could transmit electrically the quality or timbre of one sound could be made to do the same for any sound and consequently could transmit the sound of the voice.

Such an undulatory current had undoubtedly been accidentally generated many times before — any set of Morse telegraph instruments will do it — but never before had it been observed by a man whose mind had been opened by years of pondering on a great idea and so made ready to grasp instantly the immense import of that faint tone. Such a man was Alexander Graham Bell. Had any other ear but his been listening at that receiver when I snapped the spring, the sound would probably have passed unnoticed and the speaking telephone might have been unknown to-day. But faint as the sound was, he knew its epoch-making value, and never during the long and tedious experiments that followed did I know him to lose his enthusiasm or to doubt his final success.

To one not familiar with the science of acoustics, some further explanation of the occurrence of the afternoon may not be amiss. Vibrations caused in the air by a sound may be likened to the waves on the surface of a pond on a windy day. The large waves correspond to the pitch, and the smaller waves, superposed on the others, correspond to the overtones or timbre, of a sound. Up to that time all attempts to transmit sound electrically had been made by means of an intermittent or interrupted electric current and consequently had failed utterly, for the intermittent current can carry only the larger of these sound waves — the pitch — and absolutely fails to carry the innumerable small waves that are superposed on the larger waves.

Without these small waves or "overtones" the character of the sound coming from the receiving instrument is entirely changed and bears no resemblance to the original sound. It would be impossible to tell whether it came from a cornet, a piano, a violin, or the voice. The result in the receiving instrument will always be the same harsh, nasal drone. But the current generated by the vibration of the magnetized spring that I snapped had in it all these delicate overtone waves as well as the larger pitch waves, and the fact that the sound heard by Mr. Bell in his receiver had the same timbre as the spring I was snapping was to him conclusive evidence of this. That afternoon, for the first time in history, all the conditions were right, all the waves both large and small, of a sound, were impressed on an electric current, were carried by that current over a wire, and changed back into sound by an apparatus sufficiently sensitive to respond to such delicate vibrations, with the prepared man listening to it.

After the dramatic incident of June second the harmonic telegraph was dropped and earnest work on the speaking telephone began. It was a simple matter to attach a stretched drumhead of parchment to the steel spring that I had snapped and to arrange a mouthpiece to concentrate the voice upon it, so that the spring would be forced to follow the vibrations of the voice instead of vibrating at its normal rate as it did when plucked. These attachments were immediately made. The remodeled instrument was the first speaking telephone. As soon as it was ready we tried it, late one night, on a wire run between the third and fifth floors of the manufacturing building, 109 Court Street, Boston. I could hear very faintly two or three words when Mr. Bell shouted into the telephone at his end of the wire but my voice was not

strong enough to make him hear until further improvements had been made in the instruments.

Soon after this Mr. Bell transferred his apparatus to a laboratory which he had fitted up in the boarding house at 5 Exeter Place, Boston (since torn down and rebuilt as a commercial block). Many experiments on the telephone were made during the next few months, testing all sorts of variations in the original apparatus, but it was a delicate child and very slow in learning to talk plainly. The first time it ever uttered complete and intelligible sentences — faint but distinct — was on March 10, 1876. It is certainly to be regretted that on so epochal an occasion the instrument was not on dress parade. There is nothing in the history of the telephone to match the famous first message of Morse's telegraph, "What hath God wrought!"

The first recorded message carried by telephone was commonplace enough. It was simply: "Mr. Watson. . . . Please come here. . . . I want you." Probably if Mr. Bell had at that time thought that he was making history he would have been better prepared with a sounding sentence.

There was little of dramatic interest about this occasion. It was merely one of an extensive series of experiments in which either some improvement in the mechanism or some increase in our expertness in using it, made the difference between indistinctness and distinctness. But after this the improvement was more rapid, and in the early summer of 1876 it had become possible to converse quite fluently between two rooms.

The Bell telephone was exhibited at the Centennial in June, 1876. Its effect on the minds of the judges is shown in the following extract from the report of Sir William Thompson on Mr. Bell's exhibit, in which, after describing the instruments, he says:

"With my ear pressed against this disc, I heard it speak distinctly several sentences, first of simple monosyllables, 'To be or not to be' (marvellously distinct); afterwards sentences from a newspaper, 'S. S. Cox has arrived' (I failed to hear the 'S. S. Cox' but the 'has arrived' I heard with perfect distinctness; then 'City of New York,' 'Senator Morton,' 'The Senate has passed a resolution to print a thousand extra copies,' 'The Americans in London have made arrangements to celebrate the Fourth of July.' I need hardly say that I was astonished and delighted, so were the others, including some other judges of our group, who witnessed the experiment and verified with their own ears the electric transmission of speech. This, perhaps the greatest marvel hitherto achieved by the electric telegraph, has been obtained by appliances of quite a homespun and rudimentary character."

The evening of October 9, 1876, was the date of the next important experiment. We took the baby outdoors for the first time! The use of a private telegraph line belonging to the Walworth Manufacturing Company was obtained, connecting their office on Kilby Street, Boston, with their manufactory on Main Street, Cambridgeport, a distance of about two miles. Mr. Bell was at the Kilby Street station and I at the Cambridgeport end. On receiving the agreed signal on the telegraph instrument, I disconnected it from the circuit, connected the telephones, and listened for Mr. Bell's voice. I could hear only the faintest murmur, reminding me of the faint sounds that I heard in the experiment more than a year before.

What was the matter? Could it be that there was some condition in an actual telegraph line that the telephone, though working so well in the laboratory, could not fulfil? For a while it certainly looked so. I spent some time in adjusting the instruments, but with no improvement in the

result. As a last resort I carefully traced the wires which ran in rather a complicated way through the building before connecting to the outdoor wire. In an adjoining room I found a high resistance telegraph-relay in the circuit. I cut this out, ran back to the telephone, and listened.

The relay had been the sole cause of the trouble, for clearly and distinctly from the telephone came the sound of Mr. Bell's voice, and we found that we could talk with perfect ease although we were two long miles apart! As doubt had been expressed as to the possibility of the transmission of messages by the telephone with sufficient accuracy to compete with the telegraph, we wrote down what we each said and heard, and a later comparison of these notes shows a quite perfect accuracy of transmission that silenced the skeptics. By this means, the first conversation ever carried on by a telephone was preserved. It is of historic interest and a portion of it may be worthy of reproduction here.

FIRST TELEPHONE CONVERSATION

Bell: What do you think was the matter with the instruments?

Watson: There was nothing the matter with them.

Bell: I think we were both speaking at the same time.

Watson: Can you understand anything I say?

Bell: Yes; I understand everything you say.

Watson: The reason why you did not hear at first was because there was a relay in the circuit.

Bell: You may be right, but I found the magnet of my telephone touching the membrane.

Watson: I cut this relay out and then the sounds came perfectly.

Bell: I hear every syllable. Try something in an ordinary conversational voice.

Watson: Shall I connect their battery in the circuit?

Bell: No; there is no necessity to connect their battery in the circuit, for the sounds came out quite loudly.

Watson: I am now talking in quite a low tone of voice.

Bell: The sounds are quite as loud as before and twice as distinct.

Watson: Cut out the battery and then talk.

Bell: All right. I will cut out the battery now if you will keep listening. . . . I thought you were going to say something.

Watson: Is the battery cut out?

Bell: No; but I will do it now. Did you hear anything?

Watson: No; not a sound.

Bell: Say something to me when I cut out the battery again. I fancy I heard a trace of your voice.

Watson: Shall I put on our battery to see if it increases the effect?

Bell: I 'll tell you what we 'll do. We 'll take off our battery and put on theirs as before.

Watson: Is our battery off?

Bell: Yes, our battery is off. What have you been doing? The sounds were quite soft at first, but now they are quite loud. Shall I put in our battery again?

Watson: That was very indistinct. Put on our battery.

Bell: We may congratulate ourselves upon a great success.

Watson: The time by my watch is five minutes past ten. Had I not better go into Boston?

Bell: Yes. I think it is time to stop now.

Watson: Shall I go to Exeter Place?

Bell: Yes; but look in here on your way, in case I have not gone.

Watson: Let us talk conversationally without noting.

We continued the conversation until nearly midnight, and then I disconnected the telephone, restored the line to its former condition, bade good night to the wondering watchman, — my sole companion during the evening, — and went back to Boston scarcely able to conceal from the other passengers on the horse car my elation at the result of the evening's work. But joyous as I was, it was nothing in comparison with the effect the experiment had on Mr. Bell. I found that he had gone from the Kilby Street office and I went to our laboratory. He had not as yet returned, but it was not long before I heard him bounding up the stairs, and bursting into the room, his face beaming with joy and exultation, he grasped me by the shoulders, whirled me around and exclaimed, "Watson, this night's work will make me famous."

PROGRESS IN WIRELESS TELEGRAPHY[1]

BY GUGLIELMO MARCONI

THE discoveries connected with the propagation of electric waves over long distances, and the practical applications of telegraphy through space, have been to a great extent the result of one another.

The application of electric waves to the purposes of wireless telegraphic communication between distant parts of the earth, and the experiments which I have been fortunate enough to be able to carry out on a larger scale than is attainable in ordinary laboratories, have made it possible to investigate phenomena and note results often novel and unexpected. In my opinion many facts connected with the transmission of electric waves over great distances still await a satisfactory explanation.

In sketching the history of my association with radiotelegraphy, I might mention that I never studied physics or electrotechnics in the regular manner, although as a boy I was deeply interested in these subjects. I did, however, attend one course of lectures on Physics under the late Professor Rosa, at Leghorn, and I was, I think I might say, fairly well acquainted with the publications of that time dealing with scientific subjects, including the works of Hertz, Branly and Righi. At my home near Bologna, in Italy, I began early in 1895 to carry out tests and experiments with the object of determining whether it would be possible by means of Hertzian waves

[1] From "The Scientific American."

to transmit to a distance telegraphic signs and symbols without the aid of connecting wires. After a few preliminary experiments with Hertzian waves I became very soon convinced that if these waves or similar waves could be reliably transmitted and received over considerable distances a new system of communication would become available possessing enormous advantages over flashlights and optical methods, which are so much dependent for their success on the clearness of the atmosphere. My first tests were carried out with an ordinary Hertz oscillator and a Branly coherer as detector, but I soon found out that the Branly coherer was far too erratic and unreliable for practical work.

After some experiments I found that a coherer differently constructed, and consisting of nickel and silver filings placed in a small gap between two silver plugs in a tube, was remarkably sensitive and reliable. This improvement, together with the inclusion of the coherer in a circuit tuned to the wave length of the transmitted radiation, allowed me gradually to extend up to about a mile the distance at which I could affect the receiver.

Another, now well-known, arrangement which I adopted was to place the coherer in a circuit containing a voltaic cell and a sensitive telegraph relay actuating another circuit, which worked a tapper or trembler and a recording instrument. By means of a Morse telegraphic key placed in one of the circuits of the oscillator or transmitter, it was possible to emit long or short successions of electric waves, which would affect the receiver at a distance and accurately reproduce the telegraphic signs transmitted through space by the oscillator. With such apparatus I was able to telegraph up to a distance of about half a mile. Some further improvements were obtained by using reflectors with both the transmitters and re-

ceivers, the transmitter being in this case a Righi oscillator. This arrangement made it possible to send signals in one definite direction, but was inoperative if hills or any large obstacle happened to intervene between the transmitter and receiver.

In August, 1895, I discovered a new arrangement which not only greatly increased the distance over which I could communicate, but also seemed to make the transmission independent of the effects of intervening obstacles. This arrangement consisted in connecting one terminal of the Hertzian oscillator, or spark producer, to earth, and the other terminal to a wire or capacity area placed at a height above the ground, and in also connecting at the receiving end one terminal of the coherer to earth and the other to an elevated conductor. I then began to examine the relation between the distance at which the transmitter could affect the receiver, and the elevation of the capacity areas above the earth, and I very soon definitely ascertained that the higher the wires or capacity areas, the greater the distance over which it was possible to telegraph.

Thus I found that when using cubes of tin about thirty centimeters side as elevated conductors or capacities, placed at the top of poles two meters high, I could receive signals at thirty meters distance, and when placed on poles four meters high at one hundred meters, and at eight meters high at four hundred meters. With larger cubes of a one hundred centimeters side, fixed at a height of eight meters, signals could be transmitted twenty-four hundred meters all around. These experiments were continued in England, where, in September, 1896, a distance of one and three-fourths miles was obtained in tests carried out for the British government at Salisbury. The distance of communication was ex-

tended to four miles in March, 1907, and in May of the same year to nine miles. In all these experiments a very small amount of electrical power was used, the high-tension current being produced by an ordinary Rühmkorff coil. The results obtained attracted a good deal of public attention at the time, such distances of communication being considered remarkable.

As I have explained, the main feature in my system consisted in the use of elevated capacity areas, or vertical wires, attached to one pole of the high-frequency oscillators and receivers, the other pole of which was earthed. The practical value of this innovation was not understood by many physicists for quite a considerable period, and the results which I obtained were by many erroneously considered simply due to efficiency in details of construction of the receiver, and to the employment of a large amount of energy. Others did not overlook the fact that a radical change had been introduced by making these elevated capacities and the earth form part of the high-frequency oscillators and receivers.

The necessity or utility of the earth connection has been sometimes questioned, but in my opinion no practical system of wireless telegraphy exists where the instruments are not connected to earth. By "connecting to earth" I do not necessarily mean an ordinary metallic connection as used for ordinary wire telegraphs. The earth wire may have a condenser in series with it, or it may be connected to what is really equivalent, a capacity area placed close to the surface of the ground.

It is now perfectly well known that a condenser, if large enough, does not prevent the passage of high-frequency oscillations, and, therefore, in these cases the earth is for all practical purposes connected to the antennæ. After numerous tests and demonstrations in Italy

and in England over distances varying up to forty miles, communication was established for the first time across the English Channel between England and France in March, 1899.

At the time (in 1899) when communication was first established by means of radiotelegraphy between England and France, much discussion and speculation took place as to whether, or not, wireless telegraphy would be practicable for much longer distances than those then covered, and a somewhat general opinion prevailed that the curvature of the earth would be an insurmountable obstacle to long-distance transmission, in the same way as it was, and is, an obstacle to signaling over considerable distances by means of light flashes. Difficulties were also anticipated as to the possibility of being able to control the large amount of energy which it appeared would be necessary to cover long distances. What often happens in pioneer work repeated itself in the case of radiotelegraphy — the anticipated obstacles or difficulties were either purely imaginary or else easily surmountable, but in their place unexpected barriers manifested themselves, and recent work has been mainly directed to the solution of problems presented by difficulties which were certainly neither expected nor anticipated when long distances were first attempted.

With regard to the presumed obstacle of the curvature of the earth, I am of opinion that those who anticipated difficulties in consequence of the shape of our planet had not taken sufficient account of the particular effect of the earth connection to both transmitter and receiver, which earth connection introduced effects of conduction generally at that time overlooked. Physicists seemed to consider for a long time that wireless telegraphy was solely dependent on the effect of free Hartzian radiation

through space, and it was years before the probable effect of the conductivity of the earth between the stations was satisfactorily considered or discussed.

I carried out some tests between a shore station and a ship at Poole, in England, in 1902, for the purpose of obtaining some data on this point, and I noticed that at equal distances a perceptible diminution in the energy of the received waves always occurred when the ship was in such a position as to allow a low split of sand about one kilometer broad to intervene between it and the land station. I, therefore, believe that there was some foundation for the statement so often criticized, which I made in my first English patent of June 2, 1896, to the effect that when transmitting through the earth or water I connected one end of the transmitter and one end of the receiver to earth.

The belief that the curvature of the earth would not stop the propagation of the waves, and the success obtained by syntonic methods in preventing mutual interference, led me in 1900 to decide to attempt the experiment of testing whether or not it would be possible to detect electric waves over a distance of four thousand kilometers, which, if successful, would immediately prove the possibility of telegraphing without wires between Europe and America. The experiment was, in my opinion, of great importance from a scientific point of view, and I was convinced that the discovery of the possibility to transmit electric waves across the Atlantic Ocean, and the exact knowledge of the real conditions under which telegraphy over such distances could be carried out, would do much to improve our understanding of the phenomena connected with wireless transmission.

The transmitter erected at Poldhu, on the coast of

Cornwall, was similar in principle to the one I have already referred to, but on a very much larger scale than anything previously attempted. The power of the generating plant was about twenty-five kilowatts.

Numerous difficulties were encountered in producing and controlling for the first time electrical oscillations of such power. In much of the work I obtained valuable assistance from Professor J. A. Fleming, Mr. R. N. Vyvyan, and Mr. W. S. Entwistle. My previous tests had convinced me that when endeavoring to extend the distance of communication, it was not sufficient merely to augment the power of the electrical energy of the sender, but that it was also necessary to increase the area or height of the transmitting and receiving elevated conductors. As it would have been too expensive to employ vertical wires of great height, I decided to increase their number and capacity, which seemed likely to make possible that efficient utilization of large amounts of energy.

For the purpose of the test, a powerful station had been erected at Cape Cod, above New York, but the completion of the arrangements at that station were delayed in consequence of a storm, which destroyed the masts and antennæ. I, therefore, decided to try the experiments by means of a temporary receiving station erected in Newfoundland, to which country I proceeded with two assistants about the end of November, 1901.

The tests were begun early in December, 1901, and on the twelfth of that month the signals transmitted from England were clearly and distinctly received at the temporary station at St. John's, in Newfoundland. Confirmatory tests were carried out in February, 1902, between Poldhu and a receiving station on the steamship "Philadelphia," of the American line. On board

this ship readable messages were received by means of a recording instrument up to a distance of one thousand five hundred and fifty-one miles, and test letters as far as two thousand and ninety-nine miles from Poldhu.

The tape records obtained on the "Philadelphia" at the various distances were exceedingly clear and distinct.

These results, although achieved with imperfect apparatus, were sufficient to convince me and my coworkers that by means of permanent stations and the employment of sufficient power it would be possible to transmit messages across the Atlantic Ocean in the same way that they were sent over much shorter distances.

A result of scientific interest which I first noticed during the tests on the steamship "Philadelphia," and which is a most important factor in long-distance radiotelegraphy, was the very marked and detrimental effect of daylight on the propagation of electric waves at great distances; the range by night being usually more than double that attainable during daytime. I do not think that this effect has as yet been satisfactorily investigated or explained. At the time I carried out the tests I was of opinion that it might be due to the loss of energy at the transmitter, caused by the diselectrification of the highly charged transmitting elevated conductor under the influence of sunlight.

I am now inclined to believe that the absorption of electric waves during the daytime is due to the ionization of the gaseous molecules of the air affected by ultraviolet light, and as the ultra-violet rays, which emanate from the sun, are largely absorbed in the upper atmosphere of the earth, it is probable that the proportion of the earth's atmosphere which is facing the sun will contain more ions or electrons than that portion which is in darkness, and therefore, as Sir J. J. Thomson has shown,

this illuminated and ionized air will absorb some of the energy of the electric waves.

During the year 1902 I carried out some further tests between the station at Poldhu and a receiving installation erected on the Italian cruiser "Carlo Alberto," kindly placed at my disposal by the King of Italy. During these experiments the interesting fact was observed that even when using waves as short as one thousand feet, intervening ranges of mountains, such as the Alps or Pyrenees, did not, during the nighttime, bring about any considerable reduction in the distance over which it was possible to communicate. During daytime, unless much longer waves and more power were used, intervening mountains greatly reduced the apparent range of the transmitter. Messages and press dispatches of considerable length were received from Poldhu.

With the active encouragement and financial assistance of the Canadian government, a high-power station was constructed at Glace Bay, Nova Scotia, in order that I should be able to continue my long-distance tests with a view to establishing radiotelegraphic communication on a commercial basis between England and America. On December 16, 1902, the first official messages were exchanged at night across the Atlantic, between the stations at Poldhu and Glace Bay. Further tests were shortly afterward carried out with another long-distance station at Cape Cod in the United States of America, and under favorable circumstances it was found possible to transmit messages to Poldhu, three thousand miles away, with an expenditure of electrical energy of only about ten kilowatts.

In the spring of 1903 the transmission of press messages by radiotelegraphy from America to Europe was attempted, and for a time the "London Times" published,

during the latter part of March and the early part of April of that year, news messages from its New York correspondent sent across the Atlantic without the aid of cables. A breakdown in the insulation of the apparatus at Glace Bay made it necessary, however, to suspend the service, and unfortunately further accidents made the transmission of messages uncertain and unreliable. As a result of the data and experience gained by these and other tests which I carried out for the British government, between England and Gibraltar, I was able to erect a new station at Clifden in Ireland, and enlarge the one at Glace Bay in Canada, so as to enable me to initiate, in October, 1907, communication for commercial purposes across the Atlantic between England and Canada.

Although the stations at Clifden and Glace Bay had to be put into operation before they were altogether completed, nevertheless communication across the Atlantic by radiotelegraphy never suffered any serious interruption during nearly two years, until, in consequence of a fire at Glace Bay, in the autumn of 1909, it has had to be suspended for three or four months. This suspension has not, however, been altogether an unmitigated evil, as it has given me the opportunity of installing more efficient and up-to-date machinery.

Although high-power stations are now used for communicating across the Atlantic, and messages can be sent by day as well as by night, there still exist short periods of daily occurrence during which transmission from England to America, or *vice versa*, is difficult. Thus, in the morning and evening, when, in consequence of the difference in longitude, daylight or darkness extends only part of the way across the ocean, the received signals are weak, and sometimes cease altogether. It would almost

appear as if electric waves, in passing from dark space to illuminated space, and *vice versa*, were reflected in such a manner as to be diverted from their normal path. It is probable that these difficulties would not be experienced in telegraphing over equal distances north and south, on about the same meridian, as in this case the passage from daylight to darkness would occur almost simultaneously over the whole distance between the two points.

Another curious result, on which hundreds of observations continued for years leave no further doubt, is that regularly, for short periods, at sunrise and sunset, and occasionally at other times, a shorter wave can be detected across the Atlantic in preference to the longer wave normally employed. Thus, at Clifden and Glace Bay, when sending on an ordinary coupled circuit arranged so as simultaneously to radiate two waves, one twelve thousand five hundred feet, and the other fourteen thousand seven hundred feet, although the longer wave is the one usually received at the other side of the ocean, regularly about three hours after sunset at Clifden and three hours before sunrise at Glace Bay the shorter wave alone was received with remarkable strength, for a period of about one hour. This effect occurred so regularly that the operators tuned their receivers to the shorter wave at the times mentioned as a matter of ordinary routine.

With regard to the utility of wireless telegraphy, there is no doubt that its use has become a necessity for the safety of shipping, all the principal liners and warships being already equipped, its extension to less important ships being only a matter of time, in view of the assistance it has provided in cases of danger. Its application is also increasing as a means of communicating between

outlying islands, and also for the ordinary purposes of telegraphic communication between villages and towns, especially in the colonies and in newly developed countries. However great may be the importance of wireless telegraphy to ships and shipping, I believe it is destined to an equal position of importance in furnishing efficient and economical communication between distant parts of the world, and in connecting European countries with their colonies and with America. As a matter of fact, I am at the present time erecting a very large power station for the Italian government at Coltano, for the purpose of communicating with the Italian colonies in East Africa and with South America.

Whatever may be its present shortcomings and defects, there can be no doubt that wireless telegraphy, even over great distances, has come to stay, and will not only stay, but continue to advance. If it should become possible to transmit waves right round the world, it may be found that the electrical energy traveling round all parts of the globe may be made to concentrate at the antipodes of the sending station. In this way it may some day be possible for messages to be sent to such distant lands by means of a very small amount of electrical energy, and therefore at a corresponding small expense. But I am leaving the regions of fact, and entering the regions of speculation, which, however, with the knowledge we have gradually gained on the subject, promise results both useful and instructive.

WILLIAM BARCLAY PARSONS[1]

BY ARTHUR GOODRICH

A WELL-KNOWN "Captain of Industry," when asked some time ago to tell something of his methods of work, said after a moment's thought:

"When I squeeze lemons, what I 'm after is lemon juice. My method is to get all the juice out of each lemon before I tackle the next one."

The man who knows Mr. William Barclay Parsons well, and who, for example, lunches with him in the midst of a busy day, is not surprised if Mr. Parsons, who perhaps, in a lull in the conversation, is glancing hurriedly over the last edition of one of the daily papers, suddenly drops the sheet and looks intently into space. His eyes look far beyond the walls of the building. Perhaps they see some puzzling problem of a subway station at 135th Street; perhaps they see a conference of the Rapid Transit Board, and the brain back of them is busy with some terse sentence that will sum up an important plan; perhaps they see an addition to the great system of rapid transit he has planned and is carrying out, or they suddenly catch a glimpse of some diplomatic way by which a great corporation may be made to help the immense scheme he is giving the best part of his life to carry out. All at once he takes a pencil from his pocket and jots down a note. "There, that 's done," he says with a sigh of relief, and he is back with his friend in the restaurant again.

[1] By courtesy of "The World's Work." Copyright 1903, by Doubleday, Page & Company.

An "infinite capacity for taking pains," concentration of effort, eternal thoroughness; these form one of the most characteristic reasons for the success of the man who has done more than any one else to make rapid transit a practical achievement in New York. In a Founder's Day address at Cornell he drove home this same idea with the words of St. Paul, "This *one* thing I do." Nothing left half baked; no plan half worked out; every lemon squeezed dry before the next one is cut — this is the way his results have been achieved.

When he entered Columbia College in the fall of 1875, after a period of preparatory education in England, he was an overgrown boy of sixteen. But he was immediately chosen class president. He was actively interested in every side of healthy college life. He captained the tug-of-war team and stroked the crew. Columbia men of that time still tell the story of how young Parsons, in an open eight-oared race on the Harlem River, pulled the Columbia crew together after an accident that had put them behind, and with indomitable pluck stroked them almost to victory against impossible odds. All this athletic training undoubtedly developed and made solid for tireless labor his big-boned, stalwart physique.

After his graduation from college he entered the School of Mines in an engineering course. The subject absorbed his interest, and he took his engineering degree after making the highest general percentage in scholarship on record in the institution. He had spent his summer vacations in practical mining and railway work, and on leaving the School of Mines in 1882 he took a subordinate position in the office of the division superintendent of the Erie Railroad at Port Jervis. So quickly did he grasp the practice of his craft that in 1883 he published a little work entitled "Turnouts" that was adopted

— and is still used — as a textbook in the School of Mines from which he had graduated the year before. In 1884 he wrote a practical treatise on maintenance of way, a sort of trackman's *vade mecum,* which is even now considered a standard.

From Port Jervis he was transferred to the Rochester Division, and at once he began the reconstruction of a wretched stretch of roadbed. While he was at this work, his father, from whom he probably inherited much of his calmness and self-possession, came to see him. Mr. Parsons, Sr., accompanied his son on a trip over the division, and when the young supervisor told him about the bad condition of the track, he said frankly that he thought it remarkably smooth and solid.

"Oh, but this is the part I have rebuilt," his son explained. "We 'll come to the end of it in a minute and then you 'll notice the difference."

Before his father had time to reply, the train was thrown from the track by the breaking of a driving-wheel of the locomotive and landed upside down at the bottom of a fourteen-foot embankment. Father and son found themselves seated opposite each other, unhurt, on the ceiling of the car.

"There, what did I tell you?" remarked young Parsons quietly.

"Yes, son, it is rougher," his father admitted readily.

After two years of further railway construction work Mr. Parsons decided, in 1886, to go to New York, and he opened an office there as a consulting engineer with Mr. S. A. Reed, his brother-in-law. Mr. Reed had advised him to make this change because the Arcade Railroad Company planned to build a tunnel the entire length of Broadway, and there would be interesting things for engineers to watch and to do.

This was the turning point, and the decision he made has meant much to Mr. Parsons and infinitely more to the metropolis. Once his mind was interested in underground construction and in the rapid transit problem, he concentrated a large part of his time upon a careful study of it. The Arcade Railroad Company failed, and when the District Railroad Company was organized Mr. Parsons became a member of its engineering staff. The City Railroad Company replaced the District Company after it had done much hard work to no purpose, and it, in turn, went no further than Mr. Parsons's plans, which he is probably glad were never perpetuated in iron and concrete. Through all this succession of failures he was learning all about every foot of land on Manhattan Island and the foundation was being laid for his achievement. At the same time he was actively interested in practical railroad construction in many parts of the country.

In 1891, under the leadership of Mayor Hewitt, the city began to take an interest in the rapid transit idea. Already congestion was common in the rush hours, and there were demands for a practical solution of the problem. Mr. Parsons drew up an elaborate and comprehensive plan and submitted it to the first Rapid Transit Commission. He was shortly afterward appointed Deputy Chief Engineer. But no bids were received when the franchise was offered for sale, and the Commission disbanded in 1893. Then came the appointment of a new commission, and for two or three years difficulty after difficulty blocked the way of final achievement. The questions of route, of expense, of objections from property holders and many others seemed impossible to solve.

Mr. Parsons was now Chief Engineer to the Commission. An incident which it is said had much to do with his

appointment is characteristic. He was put on the witness stand at one of the court hearings and the opposing lawyers put questions to him which they were certain he would be unable to answer. But he met every query immediately, and told them the exact condition of particular localities all along the route, the number and character of the sewer pipes, the water drains, the exact measures necessary to carry out the plan proposed, all in a tense, quiet way which proved him a thorough master of the thing he was to do.

He was only thirty-five years old when he became Engineer-in-Chief to the Commission, and many veterans of the profession said openly that his appointment was a mistake; but the Commission wanted a young man — no one but a young man could possibly complete the inevitably immense plan they were beginning, and no engineer seemed to know the ground or to have such thoroughly practical plans as Mr. Parsons. And he impressed them, as he had his college mates, with an instinctive belief in his leadership.

During one of the disheartening periods after the plans for a subway up Broadway had been finally rejected, the Commission had almost given up the entire scheme as impracticable. But Mr. Parsons would not quit. He stood practically alone behind the project, and voluntarily agreed to work out an entirely new set of plans that would meet the many requirements, if the members of the Commission would keep together. The original plan of the present Elm Street route was the result of this individual work, and this was finally approved in 1898. The consolidation of the borough into the greater city, however, had so diminished the constitutional debt-incurring margin of the city that the practical achievement was again delayed.

At about this time came the war with Spain, and Mr. Parsons helped to organize a regiment of engineers from New York. He was appointed Chief of Engineers on Governor Black's staff with a rank of Brigadier General, and was placed in command of the State Camp at Peekskill, where the regiment was ordered for muster and instruction. Following this experience he was appointed Engineer-in-Chief of the Hankow-Canton Railroad. Hankow is the Chicago of the Chinese Empire, Canton its New York, and the crudest methods of transportation connected the two cities.

With a few Americans and a motley crowd of Chinese Mr. Parsons tramped on foot through the closed province of Hunan, half as large again as New York State and containing twenty-two million people. No foreigner had ever gone through it before. But, carefully untwisting miles of bureaucratic red tape, pushing ahead with indomitable will, making friends and admirers of men who were prepared to distrust and hate him, Mr. Parsons completed, in a remarkably short time, a preliminary survey, which many had prophesied could never be accomplished.

As a member of the expedition described the task, "he did it on tact and absolute fairness of treatment to officials and peasantry alike. Prepared to fight, he never made the least show of willingness to do so, and we got through without friction, though often in much danger. Rapid transit requires generalship, of course, but it's the generalship of field maneuvers. When compared with that thousand-mile march in a hostile country from Hankow to the sea, Sherman's march was nothing to it."

So successful was the result of Mr. Parsons's work in China that he not only received what is said to have been the largest fee ever paid for a preliminary railway survey, but he is now the president of the railroad company

and the line is already well under way. Two gayly painted engines, decorated with Chinese hieroglyphics, now helping in the construction of the road, used to pull crowded trains of elevated cars in New York before the installation of electricity. Thus Mr. Parsons washes the left hand of his work in Asia with the right hand of his work in America.

When he arrived in New York the Rapid Transit Commission was ready for him. At last the great scheme at which he had been working for years was to begin. How badly it was needed only people familiar with New York can know.

It has been said that Mr. Parsons is as thorough as a machine — that he concentrates to get one thing done at a time. If we follow him once through his daily routine the large facts of the man's character are as evident as his already great achievement. His kindly eyes, his firm and heavy, almost threatening, jaw, his quiet but decisive voice, suggest contrasts of character at the start.

If you sit in Mr. Parsons's office and look out of the big windows over the pulsing island city, the rivers on either side, the crowded narrow streets, the towering buildings, you will suddenly feel the immense sweep of this man's work, which is knitting together the parts of the greater city by traffic paths underground and elevated above it, by tunnels under rivers, by bridges over them — the most remarkable system of rapid transit plans ever proposed. He must have the imagination of creative genius. Go out through his offices and you will find room after room of hard-working engineers and draftsmen, organized carefully and having splendid *esprit de corps*. These men work out the plans he creates. He does not allow himself to be swallowed up

in detail, but as often as he looks over the detailed plans he will put his finger upon many little flaws that have passed by the men who have made them. He checks the work carefully. The men who work with him all believe in him thoroughly both as engineer and man. A man who can command such a force of skilled employees must have remarkable executive ability.

In his little spare time many things occupy his mind. A man who did some private work for him remarked, "One day it was a railroad at Pittsburg, the next the Chinese railroad, the next some work for an encyclopedia." He is gratuitously helping London engineers with their rapid transit problem. He has done a good deal of writing and has made a number of important public addresses. A man who knew him well said that Mr. Parsons would never overwork or burden himself. His sense of humor would save him. There was abundant evidence of this quiet humor in a remark of his one day: "Did you ever write a book? No? Well, don't. It 's too expensive a luxury of labor."

He is a very genuine man and a genuinely kindly man. Not long ago he went to Europe on some matters of business and was received with considerable ceremony by many leaders of English progress. He had a dozen or more large plans to carry out, and yet, when an employee of his who went abroad for a rest some weeks after Mr. Parsons had gone, arrived at a London hotel six hours later than the time which had been scheduled, the man was astonished to find awaiting him an anxious wire from Mr. Parsons inquiring for his safe arrival. And the same thing happened later in Paris. He is a man who naturally likes people and enjoys showing that he likes them.

His home means more to him than his clubs, although

he is a member of a number of the best ones. He is the youngest trustee of Columbia College and a vestryman of old Trinity Church, New York. He is fond of yachting, but he takes his recreation chiefly in varying work with other work.

A man with an imagination that plans great things, with thoroughness doing one thing at a time and that one thing well; with executive power and a genius for leading men; with the skill and tact of a trained diplomat, and with an unalterable determination that gets great plans, thoroughly handled by thousands of men under his direction, done on time; and a kindly man with a genial sense of humor; modest, as one man put it, "because he does n't know any better"; not without faults, but seeming to lack any that might interfere with his highest efficiency,— such a man is William Barclay Parsons. The fact that he and men like him are doing the most important public service should brace up the weak backs of those who fear for the republic.

THE AIR—OUR TRUE HIGHWAY[1]

BY LIEUTENANT FRANK LAHM, U. S. A.

THE experimental stage in aërial navigation is past. Not only has the success of the Wright brothers with their aëroplane proved that this problem has been solved, but various types of dirigible balloons have been controlled while aloft for such a length of time and for such a distance as further to verify the conquest of the air that man has achieved.

Yet only a century and a quarter has elapsed since the first device conceived by man floated above the earth, when the Montgolfiers, the French bag-makers, filling their silken sack with smoke, sent up a hot-air balloon to a height of fully six thousand feet. That was in 1783; and in a few months two adventurers had dared to make the first aërial voyage from the city of Paris. About three-fourths of a century then elapsed before Wise, a Philadelphia carpenter, astonished all America by making his eight hundred and seventy mile journey through the atmosphere at express-train speed. This was the first long-distance balloon voyage in a century of aërial experiments; for it was not equaled until 1898, when Count de la Vaulx went from Paris across the Russian frontier, a distance of twelve hundred miles. The aërostat, or free balloon, was the sole method of navigating the world above us until, in 1884, the French engineer Renard made his first flight in an electrically propelled balloon. Then began the era of the aëronat,

[1] By courteous permission of the Author.

or second type in the series of air-craft, which the genius of inventors has since so greatly varied and improved. The aëronat is upheld by gas, is provided with a motor and one or more propellers, and can be guided in any direction, not merely drifting with the wind like the ordinary balloon.

The history of aërial navigation since the construction of the first aëronat has been interesting indeed. Various nations have vied with one another to produce the most perfect type, and so it is that such experts as Santos-Dumont, Julliot, Zeppelin, Von Gross and Baldwin have each developed designs that prove to the scientific world not merely the possibility but the entire practicability of this mode of mechanical flight. Santos-Dumont, the Brazilian, began his experiments as recently as 1898, and three years later had won the Deutsch prize by controlling his airship during a trip of seven miles, in the course of which he had to steer it around the Eiffel Tower. In four years he constructed fourteen different designs.

Count Zeppelin, who has designed the largest of all aëronats, has completed four machines in the score of years he has been giving attention to the subject. One of them had an envelope of the enormous length of four hundred and forty-six feet, holding four hundred and sixty thousand cubic feet of gas, giving it a total lifting power of sixteen tons. With this Count Zeppelin made a voyage from Friedrichshafen over a part of Germany, remaining in the air over twenty hours, covering three hundred and seventy-eight miles, and carrying with him eleven passengers.

The Zeppelin design has been accepted by the German government for military purposes, and eight of the machines are to be completed in the near future. The Gross also has been approved — a dirigible driven by

two seventy-five horsepower motors, which has covered one hundred and seventy-six miles in thirteen hours. The Von Parseval, also of German conception, is a late addition. It has several peculiar features; for example, four canvas strips attached to steel arms form the blades of the propeller, the centrifugal force when the propeller revolves causing the canvas to assume the correct shape. This of course lightens the weight of the metal required. The car is adjustable and can be moved forward or backward on rollers resting on two cables, thus placing its weight as desired.

The work of Julliot has been appreciated by the French government, for his first airship, the "Lebaudy I," named after his employers, was accepted after a practical trial had demonstrated its success. "La Patrie," built later by the Lebaudy brothers for the government, was from Julliot's design. Its gas bag was two hundred feet long, and the seventy-horsepower motor drove two propellers. "La Patrie" was designed to carry four persons, and to develop a speed of over thirty miles an hour. On one trip it went to Verdun, a distance of one hundred and seventy-five miles, in seven hours; but a few days later a heavy wind broke it away from its moorings, and it was carried out to sea. Other craft of this type have been added to the French military service. M. Henri Deutsch has also given to the public service the "Ville de Paris," another type of dirigible, and it has been stationed on the German frontier.

The British have a successful steerable balloon, somewhat smaller than the French and German, but capable of playing an important part in warfare. "Dirigible Number One" of the British army made its first appearance in 1907. It appeared again, slightly modified, in 1908, and is now being operated at Aldershot. With a length of

one hundred and eleven feet and a capacity of eighty-five thousand cubic feet, it is capable of carrying three persons and making a speed of twenty miles an hour. The gas bag, instead of being of cotton or silk and rubber, is made of eight layers of goldbeater's skin. This is taken from the cæcum of cattle, and the intestines of five hundred cattle are required to make a single "mold" or packet of goldbeater's skins.

While dirigible balloons have been completed and navigated in the United States for several years, their value being thoroughly demonstrated, it was impossible for our War Department to encourage inventors to build one for government service until 1908, when specifications were sent out by the Chief Signal Officer of the Army inviting bids for a balloon of this type. Among the proposals received was that of Captain Thomas Baldwin, and to him the contract was awarded. He delivered his airship in August of last year, and this is the one now known as "Dirigible Number One," in operation at Fort Myer near Washington. With a length of ninety-six feet, a maximum diameter of nineteen and a half feet and a volume of twenty thousand cubic feet, "Dirigible Number One" is designed to carry two persons. At its official trial it made a maximum speed of nearly twenty miles an hour, and remained continuously in the air for two hours, covering a distance of twenty-seven miles. With the experience gained from this small airship, the Signal Corps is now in a position to proceed with the construction of a larger and more powerful one capable of rendering valuable service in case of war.

The third form of air-craft, which is perhaps more interesting to the public because of the absence of the gas bag, we may term the aëronef, or heavier-than-air machine. Three types come under the heavier-than-air

class: First, the orthopter, or flapping-wing machine, which imitates the bird; none has as yet proved successful. Second, the helicopter, which is driven upward by a horizontally placed propeller and is then driven forward by another set of propellers, or by inclining the axis of the lifting propellers. Little success has been attained with this type, though it has many stanch advocates. It has this advantage over all the others, that it can rise vertically, and therefore requires no track or level ground from which to start. The third and most interesting type is the aëroplane. This is the type with which the Wright brothers, Santos-Dumont, Farman and many others have compelled the world's attention.

Since the Wright brothers have made such a signal success of their inventions, a brief history of their efforts may be of interest in this connection. In 1896, Wilbur and Orville Wright were manufacturing bicycles in their native town of Dayton, Ohio. Being of a scientific as well as a mechanical turn of mind, they became interested in the work of Lilienthal, a German who had undertaken the solution of aërial navigation with heavier-than-air machines. Up to 1900 they had merely studied and made laboratory experiments; in that year, however, they started the actual work of building a flying machine. They selected a point on the North Carolina coast which had strong and constant winds, established a camp, and started in with a gliding machine. It was only a summer outing, but they succeeded in building a machine which carried them down a slope and covered several yards before coming to the ground.

The next summer they took another vacation and continued their gliding experiments. As yet, it was only a pastime, though they made some progress. Again in the summer of 1903 they went to their camp, and so success-

ful were their experiments that they built a motor and put it on their glider. On December 17 of that year they made four flights, the longest eight hundred and fifty-two feet, which they covered in fifty-nine seconds, against a twenty-mile wind. Success was theirs. They returned to Dayton and decided to give up bicycle building and devote themselves to the perfection of their aëroplane.

Their progress was rapid. In August, 1904, several flights reached a thousand feet in length. Having mastered the equilibrium of their machine flying in a straight line, they began to make turns, and on September 20 succeeded in making a complete circle, returning to the starting point without touching the ground. The following year, 1905, marked the final success of their experiments. In October they flew twenty-four miles in thirty-eight minutes, circling a field near Dayton. They had accomplished their object — had solved the problem of flight — had conquered the air. In December, 1907, specifications were sent out by the Chief Signal Officer of the United States Army inviting bids for a heavier-than-air machine.

The Wright brothers responded and offered to furnish a machine to fulfill all the requirements of the specifications. Had the contract been completed, the machine would have been the property of the United States Government. But, as in all new sciences, perfection is not reached without setbacks. On September 17, 1908, a broken propeller caused the unfortunate accident in which Lieutenant Thomas E. Selfridge, U.S.A., was killed and Mr. Orville Wright was almost fatally injured, and effectually prevented any further trials that year. An extension of nine months was granted the Wright brothers, which meant that delivery of the machine was to be made in the spring of 1909.

In the meantime Mr. Wilbur Wright, abroad, had not only equaled but surpassed all the records made at Fort Myer. At Le Mans, France, he flew one hour and ten minutes with a passenger, and made one flight alone lasting two hours and twenty minutes. Those who saw the Wright aëroplane circling the field at Fort Myer, under perfect control of its operator, can readily understand that the only limit to the length of flight is the amount of gasoline which can be carried to run the engine.

The Wright aëroplane which has so thoroughly demonstrated the possibility of mechanical flight may be described briefly as follows: The machine consists of two rectangular planes, rounded slightly at the rear corners and superposed, one above the other, at a distance of six feet apart. These surfaces are forty feet long by six and one-half feet wide, and have a supporting area of about five hundred square feet. They are made of unbleached muslin, tightly stretched on rectangular frames provided with curved ribs extending across the frames and beyond their rear edges for about eighteen inches. A wire is stretched tightly through the forked rear ends of the ribs, and to this wire the cloth is attached, while it also passes around the front edge of the rectangular frame and back under the ribs, completely covering them. The two frames are fastened together by sixteen tapered uprights, properly spaced apart along their front and rear edges. Four of these uprights on each end are secured to the frames of the planes by a hook-and-eye connection which makes a flexible joint.

The aëroplane is mounted upon runners, which are secured beneath its center part and extend forward and curve upward to support the horizontal rudder. This is formed of two superposed planes very similar to the main

surfaces. In the middle of the horizontal rudder there is a semicircular vertical surface, which has a steadying effect upon the steering of the machine. The vertical rudder is mounted upon two horizontal braces that project back of the machine at its middle point, and is operated by one of two levers. With a third lever are connected two wires in a manner similar to that by which those that operate the vertical rudder are connected. These wires run through pulleys at the rear of the lower main plane, and extend to the top of the outer rear connecting post.

The lower ends of the lower plane are connected by a wire passing upward through pulleys and downward again. When the lever is pulled it draws down the rear edge of the upper plane. The lower plane, being connected to it by the uprights, is also forced downward, exerting a pull upon the wire attached to it, thus raising its opposite end, which also forces upward the corresponding end of the upper plane. The ends of the planes are warped in this manner, and thus when a greater angle of incidence is obtained at one end, the angle is correspondingly lessened at the other. By twisting the planes the aviator is able to tip the machine readily and make sharp turns, also to counteract quickly the effect of gusts of wind.

The engine of the aëroplane was designed by the Wright brothers and, like the machine itself, it is of great simplicity. Its total weight is one hundred and seventy pounds. It is mounted in a fore-and-aft direction in the aëroplane, slightly to the right of the middle line of the machine as one sits in it and faces forward. The four cylinders are bolted to an aluminium crank case, and the inlet valves are connected by a suitable inlet pipe. Gasoline is pumped into this inlet pipe by a small pump in

the crank case which is driven from the crank shaft. The propellers which were used on the last trial were about nine feet in diameter, and made about four hundred revolutions a minute. Ordinarily, the motor developed about twenty-five horsepower, which was sufficient to drive the machine about forty miles an hour.

With the aëronat and aëronef available for aërial navigation we are indeed on the eve of a revolution in travel. The successful construction of these lighter-than-air and heavier-than-air machines marks the beginning of an industrial activity which will give inventors such an opportunity to show their ability as has been afforded in the creation of the automobile, and of craft for water navigation.

The air has long been a subject of investigation, and much information has recently been added to our knowledge about it; but, as I have intimated, the dirigible and the aëroplane will be of much value to science in further increasing what we know at present about this great region through which man can actually move as he moves on land and water. The extent to which aërial journeys will be possible can only be imagined as yet, but we have reached the point where we have the means of making them, and the length appears to be controlled only by the supply of liquid fuel which can be carried, which in the lighter-than-air machines is conditioned by the dimensions of the bag.

Considering the subject from a military standpoint, the aëroplane is of the utmost importance. Readily developing a speed of forty or more miles an hour, and capable of remaining in the air for four or five hours, by its means a thorough and complete reconnaissance of the strength and position of the enemy could be made by observers in a position to note the line of defense and the position

of every piece of artillery. Data could thus be obtained for maps which would be of the greatest value for strategic purposes. As a means of communication between one commander and another, as a messenger for transmitting orders and instructions, the aëroplane would prove not merely useful but essential. Should the commander-in-chief desire to confer with some subordinate perhaps a half-day's ride by the highway, physical communication could be established in a fraction of the time possible by any other means. In such a case the machine might be of vital importance as a time saver.

While this discussion may seem to be dealing with a future period, what the heavier-than-air machine has already accomplished convinces us that the prediction of its possible service is not in the least exaggerated. But the model which is lighter than air has proved that it too is necessary in modern military equipment.

Even the war balloon sustained by gas and without any motive power save the wind has served its purposes; but in the dirigible type we have a model which can ascend so far into the atmosphere that it can take advantage of the various air currents to increase its motor-created speed, while its every movement is under control of the aëronaut. He can maintain it nearly stationary over an enemy's camp or battle line, for the officer to observe every important detail and, if desired, to photograph the vista. With its aid a line of march can be followed and the movements of an army can be observed perhaps for days; yet when it is necessary to report at headquarters, a few hours only may be needed to cover the hundred miles or more and deliver the acquired information, such is the speed that may be obtained with the present type of lighter-than-air machines. So it has a part in the service quite as important as that of the other type.

Saluting the Biplane

But let us look forward briefly to the time when we shall make use of the atmosphere for traveling — making aërial journeys for pleasure, perhaps for business. Only the few who have voyaged in the world above us, and have learned somewhat of its mysteries, know the keen enjoyment, the exhilaration of moving in this atmospheric ocean. If the venture be made in the aërostat, or ordinary balloon, the preparation for the start is in accordance with an approved system. When the craft is ballasted and equipped and all are aboard, the men holding it to the earth release their grip at a signal from the pilot and the earth literally drops from beneath you. Once on the voyage science aids in determining the speed and the direction, and greatly assists in operating the great lifting machine.

The pilot must know at once when his balloon starts up or down. A little sand thrown out at the beginning of a descent will do more to stop it than a large quantity after the movement is begun. The registering barometer with a cylindrical drum and a pen is used, or more often a statoscope. When the pilot closes the rubber tube between his thumb and finger, the arrow moves to the right if the balloon is ascending, to the left if descending. The compass is of service in a balloon as long as the earth can be seen. A sextant with artificial horizon is now used for finding the latitude of the balloon when above the clouds. The north star is a valuable guide, and if you are over water, the direction of the waves will tell in what direction the wind is taking you. Maps are always carried, and by day, if the balloon does not go too high, its course can be accurately followed. A speaking trumpet or megaphone may enable you to talk with people on the earth, though the answer to your question is not always easy to understand. At a height

of three miles the oxygen in the air is insufficient to maintain life for any length of time, so a supply must be carried in a tube, with a device for inhaling. It is only in races or scientific ascensions that so great a height is reached. Ordinarily the balloon remains below a mile and a half or two miles.

No two ascensions are alike; each has its own beauties, its own charm. On one you will go for hours without exceeding a height of a thousand feet; on another you rise at once to three thousand, and possibly remain out of sight of the earth for three or four hours. Or you come down and let the three-hundred-foot guide rope trail across the fields and forests. Equilibrium is maintained automatically, as a greater or lesser length of rope trails on the ground and relieves the balloon of its weight.

But all pleasures must end, and the time comes to return to the lower world. A short pull on the valve and you drop down through the clouds, throwing out a little sand to check the descent. The guide rope touches, and you skim across woods and fields. A shout to the first person you see, and you learn where you are and how far it is to the nearest railway. An open field is directly in your path. Arriving on the edge of it, you open the valve a second, the balloon drops to within a few feet of the ground, and down goes the anchor. Relieved of its weight, the descent is stopped, and the balloon seems to wait for the anchor to grip, then settles down. Should there be much wind, the pilot tears out the "rip strip" just as the car touches the earth, and the balloon flattens out in a moment.

An hour at most is needed to remove the valve, untoggle the car, remove the net from its envelope, store it with the other equipment in the car, and if the balloon is not a large one it may be packed with the rest. Then

the cover is placed on the car and all is ready to be put aboard the wagon which has been secured, except the instruments which pilot and passengers take with them to the railway station. The balloon is sent back to the starting point, while its passengers settle down comfortably in the dining car, to discuss their dinner and the many enjoyable incidents and interesting impressions of the ascension.

The cost? It is but little in comparison with the pleasure enjoyed. The expense of the balloon service is merely the small outlay for gas and inflation. No fuel is needed, no oil, no engineer. You can buy a balloon which will carry three passengers for a fourth of the cost of a three-thousand-dollar automobile, and become your own pilot if you wish. A hundred-mile trip, including every item of expense, even to packing and returning the outfit and your railroad fare, can be made for a little more than twenty dollars a person. So we see that the pleasure craft, the free balloon, is already at our disposal; the dirigible and the aëroplane have already assumed positions of great importance in the equipment of modern armies and give us reason to believe that they will soon extend their sphere of usefulness not only as pleasure craft but commercially as well. Plainly the air is our true highway.

THE PIONEER OF AËRIAL FLIGHT[1]

THE WORK OF SAMUEL PIERPONT LANGLEY

By ALEXANDER GRAHAM BELL

WHO are responsible for the great developments in aërodromics of the last few years? Not simply the men of the present but also the men of the past.

To one man especially is honor due — our own Dr. S. P. Langley, late secretary of the Smithsonian Institution. When we trace backward the course of history, we come unfailingly to him as the great pioneer of aërial flight.

We have honored his name by the establishment of the Langley medal; and it may not be out of place on this, the first occasion for the presentation of the medal, to say a few words concerning Langley's work.

Langley devoted his attention to aërodromics at a time when the idea of a flying machine was a subject for ridicule and scorn. It was as much as a man's reputation was worth to be known to be at work upon the subject. He gravely faced the issue, and gave to the world his celebrated memoir entitled "Experiments in Aërodyanmics."

In this work he laid the foundation for a science and art of aërodromics, and raised the whole subject of aërial flight to a scientific plane.

The knowledge that this eminent man of science believed in the practicability of human flight gave a great stimulus to the activities of others and started the modern movement in favor of aviation that is such a marked feature of to-day.

[1] By permission of "The Scientific American." Copyright, 1910.

Every one now recognizes the influence exerted by Langley on the development of this art. The Wright brothers, too, have laid their tribute at his feet.

"The knowledge," they say, "that the head of the most prominent scientific institution of America believed in the possibility of human flight was one of the influences that led us to undertake the preliminary investigations that preceded our active work. He recommended to us the books which enabled us to form sane ideas at the outset. It was a helping hand at a critical time, and we shall always be grateful."

Langley's experiments in aërodynamics gave to physicists, perhaps for the first time, firm ground on which to stand as to the long-disputed questions of air resistances and reactions. Chanute says:

(a) They established a more reliable coefficient for rectangular pressures than that of Smeaton.

(b) They proved that upon inclined planes the air pressures were really normal to the surface.

(c) They disproved the Newtonian law that the normal pressure varied as the square of the angle of incidence on inclined planes.

(d) They showed that the empirical formula of Duchemin, proposed in 1836 and ignored for fifty years, was approximately correct.

(e) That the position of the center of pressure varied with the angle of inclination, and that on planes its movements approximately followed the law formulated by Joessel.

(f) That oblong planes presented with their longest dimensions to the line of motion were more effective for support than when presented with their narrower side.

(g) That planes might be superposed without loss of

supporting power if spaced apart certain distances which varied with the speed; and

(h) That thin planes consumed less power for support at high speeds than at low speeds.

The paradoxical result obtained by Langley, that it takes less power to support a plane at high speed than at low, opens up enormous possibilities for the aërodrome of the future. It results, as Chanute has pointed out, from the fact that the higher the speed the less need be the angle of inclination to sustain a given weight, and the less, therefore, the horizontal component of the air pressure.

It is true, however, only of the plane itself, and not of the struts and framework that go to make up the rest of a flying machine. In order, therefore, to take full advantage of Langley's law, those portions of the machine that offer head resistance alone, without contributing anything to the support of the machine in the air, should be reduced to a minimum.

After laying the foundations of a science of aërodromics, Langley proceeded to reduce his theories to practice.

Between 1891 and 1895 he built four aërodrome models, one driven by carbonic acid gas and three by steam engines.

On the 6th of May, 1896, his aërodrome No. 5 was tried upon the Potomac River near Quantico. I was myself a witness of this celebrated experiment, and secured photographs of the machine in the air, which have been widely published.

This aërodrome carried a steam engine, and had a spread of wing of from twelve to fourteen feet. It was shot into the air from the top of a house boat anchored in a quiet bay near Quantico.

It made a beautiful flight of about three thousand feet, considerably over half a mile. It was indeed a most inspiring spectacle to see a steam engine in the air flying

with wings like a bird. The equilibrium seemed to be perfect, although no man was on board to control and guide the machine.

I witnessed two flights of this aërodrome on the same day; and came to the conclusion that the possibility of aërial flight by heavier-than-air machines had been fully demonstrated. The world took the same view; and the progress of practical aërodromics was immensely stimulated by the experiments.

Langley afterward constructed a number of other aërodrome models which were flown with equal success, and he then felt that he had brought his researches to a conclusion, and desired to leave to others the task of bringing the experiments to the man-carrying stage.

Later, however, encouraged by the appreciation of the War Department, which recognized in the Langley aërodrome a possible new engine of war, and stimulated by an appropriation of fifty thousand dollars, he constructed a full-sized aërodrome to carry a man.

Two attempts were made, with Mr. Charles Manley on board as aviator, to shoot the machine into the air from the top of a house boat; but on each occasion the machine caught on the launching ways, and was precipitated into the water. The public, not knowing the nature of the defect which prevented the aërodrome from taking the air, received the impression that the machine itself was a failure and could not fly.

This conclusion was not warranted by the facts, and to me, and to others who have examined the apparatus, the fruit of years of labor, it seemed to be a perfectly good flying machine, excellently constructed. It was simply never launched into the air, and so has never had the opportunity of showing what it could do. Who can say what a third trial might have demonstrated? The gen-

eral ridicule, however, with which the first two failures were received prevented any further appropriation of money to give it another trial.

Langley never recovered from his disappointment. He was humiliated by the ridicule with which his efforts had been received, and had, shortly afterward, a stroke of paralysis. Within a few months a second stroke came and deprived him of life.

He had some consolation, however, at the end. Upon his deathbed he received the resolutions of the newly formed Aëro Club of America, conveying the sympathy of the members and their high appreciation of his work.

Langley's faith never wavered, but he never saw a man-carrying aërodrome in the air.

His greatest achievements in practical aërodromics consisted in the successful construction of power-driven models which actually flew. With their construction he thought that he had finished his work; and in 1901, in announcing the supposed conclusion of his labors, he said:

"I have brought to a close the portion of the work which seemed to be specially mine,— the demonstration of the practicability of mechanical flight,— and for the next stage, which is the commercial and practical development of the idea, it is probable that the world may look to others."

He was right, and the others have appeared. The aërodrome has reached the commercial and practical stage; and chief among those who are developing this field are the brothers Wilbur and Orville Wright. They are eminently deserving of the highest honor from us for their great achievements.

GEORGE WESTINGHOUSE[1]

BY THEODORE NEVIN

ONE day, many years ago, George Westinghouse happened to see a collision between two freight trains caused by the ineffectiveness of the hand brakes then in use. He wondered how trains could be stopped more quickly, and he set to work to invent a device to do it. He decided that the brake must be worked from the engine, since the engineer is the first to see any danger. He tried chains, but they would not do. Reading of the use of compressed air for driving drills in the Mount Cenis Tunnel, he experimented with this form of power. His planning and designing were begun all over again, because compressed air required new apparatus. He made drawings of an air pump and a brake cylinder and valves, and from these drawings he constructed an apparatus which he felt was worthy of a practical test.

Forthwith he went to the superintendent of the New York Central Railroad and asked him to try it. The superintendent declined. But this disappointment was merely part of the severe schooling through which Mr. Westinghouse passed in his remarkable career; for, undeterred, he went on urging the merits of his brake. There was no railroad in the country whose managers and superintendents did not know him directly or indirectly, but they would not try his device.

At last he got permission to explain the brake to Com-

[1] By courtesy of "The World's Work." Copyright, 1905, by Doubleday, Page & Company.

modore Vanderbilt, the greatest living railroad man of the period. He was himself so thoroughly convinced of the merit of his invention that he felt that, if he had the opportunity of explaining it, Commodore Vanderbilt would immediately order every car of the New York Central Railroad to be equipped with it. The interview took place in Commodore Vanderbilt's New York office. Mr. Westinghouse spoke and Commodore Vanderbilt listened. At last the old man asked,

"Do you mean to tell me that you can stop a railroad train by wind?"

"Well, yes, inasmuch as air is wind, I suppose you are right," said the inventor.

Then the great railroad man said something like this: "I have no time to waste on fools"; and the interview was ended.

But Mr. Westinghouse kept on. Even at that time he was persuasive, but he could find no backers who would risk their money in his "wild innovation." Some of his business associates considered him a crank; they told him that he was a man of one idea, and playfully dubbed him "Crazy George."

About this time he invented a railroad frog which appealed to railroad men at once. He went to Pittsburg to make arrangements with a steel company to manufacture the frogs. There he became acquainted with Andrew Carnegie, Robert Pitcairn of the Pennsylvania Railroad, and Ralph Bagley. All were young men and George Westinghouse became their companion. He told them about his brake, and asked them to take up his project with him.

At last Ralph Bagley, who owned a foundry, agreed (for one-fifth interest in the invention) to make an apparatus to equip a single train. The superintendent of the

Steubenville division of the Pan Handle Railroad from Pittsburg to Steubenville agreed to place a train of cars at the inventor's disposal, and the work went ahead. The first trial took place in October, 1868. The first application of the air brake prevented a collision between the train and a wagon. The brake had proved itself.

But Mr. Westinghouse did not sit down and rest. The newspapers and scientific journals were enthusiastic about it, but he realized that his work had merely begun. He saw better than others that the brake was still defective. When he went home from the first test he made new plans. The Westinghouse Air-brake Company was formed, and a factory was built for making the brakes to fill the orders which began to come from various parts of the country. But he bent his mind also to improving the brake and bringing it to a degree of perfection which he had conceived on the day the two trains collided near Troy.

Having now convinced the railroad men of the United States of the practicability of his invention, he went to Europe to introduce the brake there. From that time he has developed his brake to keep step with the development of the railroad business.

His next big project was that of piping natural gas into Pittsburg. While natural gas was piped into the Steel City as early as 1883 by a few individual manufacturers for their mills and factories, the gas fields with large supplies were so far away (according to the limited ideas of the time) that no one had the courage to lay a pipe line to bring the gas in quantity to the city. It would be too expensive. No one dared to take the risk of sinking the millions of dollars necessary to do the work. But Mr. Westinghouse carefully computed the cost of bringing the gas from the Murraysville field, about forty miles distant, the nearest of the large gas-producing fields, and also the

possibilities of profit in selling it in the mills and homes of Pittsburg.

He became convinced that the project was entirely feasible and that the profits to the man or the company who undertook it would be incalculable. So in May, 1885, he set about to form a company — the Philadelphia Company. He needed six million dollars to carry out his plans, and twenty years ago six million dollars looked much larger in Pittsburg than it does now. The scope of the work was outlined and public subscriptions were invited. So confident was he that he feared there would be such a crowd in front of the bank where the subscriptions were to be received that policemen would be needed to keep order. The day for receiving subscriptions came, but not the expected crowd. But this rebuff only spurred him on. He went among his friends, used his magic powers of personal solicitation, succeeded in inspiring them with his own enthusiasm, got all necessary money subscribed, and carried his plan to completion. It made a fortune for every one who went into it, and by cheapening fuel it gave a great impetus to the manufacturing industries of Pittsburg.

In the meantime Mr. Westinghouse had found other battle grounds. During his sojourn in Europe he had studied the system of electrical distribution then in vogue, which interested him. Electric lighting was in its infancy. Mr. Westinghouse, with characteristic foresight, soon recognized the possibilities of the "new" element of light and power. In Paris he learned of Gaulard and Gibbs, two engineers who had recently obtained patents on the "alternating-current" system of electrical distribution. The "direct-current" system then in use was too costly for general introduction as a means of lighting. The alternating-current system was cheaper. Mr. Westing-

house bought Gaulard and Gibbs's patents, though not even he foresaw the tremendous advantages of the new method of distribution.

After returning to the United States he engaged William Stanley, Oliver B. Shallenberger, and other young electricians to develop the new system. The apparatus was designed, and a corporation known as the Westinghouse Electric Company was organized to manufacture, sell, and install alternating-current apparatus for electric lighting. At this time Mr. Westinghouse no longer had to depend upon others to foster his plans. The air brake had already made him rich. So, apparently well fortified to carry his project to a quick and satisfactory conclusion, he really entered upon the "fight of his life."

The electrical industry of the country was very small, but it was headed by Thomas A. Edison, and it was backed by a coterie of powerful financiers. These men had never been known to give up anything without a fight. The opposition aroused against Mr. Westinghouse and his new system was most powerful; it cropped up everywhere — in courts, in the legislatures of States, in the council chambers of municipalities, in Congress even.

Mr. Westinghouse met his adversaries at every turn. In spite of the opposition, contracts kept coming in; and the apparatus was installed by almost every company in the country. It was installed in London, England, in what was then the largest electric-lighting establishment in the world. In the end the opponents of the alternating-current system were compelled to retreat, and from that time the direct-current system of lighting was no longer heard of. Then the adversaries of Mr. Westinghouse turned other batteries upon him.

An older electrical company was manufacturing an incandescent lamp patented by Mr. Thomas A. Edison,

known as the Edison lamp. Wherever Mr. Westinghouse sold his alternating-current machine, his customers were obliged to buy lamps from his opponents. So it was intimated to the Westinghouse customers that, if they bought Westinghouse apparatus, they could not buy any lamps. On discovering this fact, Mr. Westinghouse brought out a lamp known as the Sawyer-Man incandescent lamp, manufactured after a patent granted to Sawyer and Man. Litigation began. A legal battle, which lasted for years and cost hundreds of thousands of dollars, was waged, till the Supreme Court of the United States decided in 1893 that the Sawyer-Man lamps were an infringement on the Edison patent. At this time Mr. Westinghouse had just received the enormous contract of the World's Fair at Chicago to supply ten five-thousand-horsepower generators and two hundred and fifty thousand incandescent lamps. But Mr. Westinghouse was not deterred. He smilingly assured his friends that there was nothing to be alarmed about.

The surprise came in February, 1893. Mr. Westinghouse placed upon the market a Sawyer-Man stopper lamp, an incandescent lamp made in two parts, entirely different from the Edison lamps in its essential feature. It is not so durable as the Edison lamp, but for a short period it gives as brilliant a light. He then took the initiative in legal proceedings. He called the representatives of the Edison interests into court to show cause why he should not manufacture this lamp. This was a master stroke of strategy, and his success was complete. He supplied the machinery at the World's Fair and he supplied the lamps, presenting the most marvelous display of electrical illumination that had been seen up to that time.

But the saddest trial of his life came in 1890 and 1891. Owing to the financial situation of the country and the

mismanagement of the affairs of the Westinghouse Electric Company, that company stood at the brink of ruin before he knew it. But, with characteristic energy, he discharged the general manager and other employees and tried to restore order from the chaos. He invited Pittsburg bankers into a conference. They declined to help him. He offered his large private property, his own house in Pittsburg, as collateral, but they declined. The situation was grave.

When he was finally persuaded that there was no hope of doing anything in Pittsburg, he boarded his private car and went to New York, where he was then comparatively unknown. In New York he secured all the money he needed. The electrical company was reorganized and placed upon a better footing than ever. But the experience caused him to keep always a close grip on his affairs, and there is no doubt that to-day he is one of the world's hardest and most tireless workers.

In closing it might be asked: What is his ambition? What is he working for? Not money, for he has that in superabundance. Not fame, for he has that. He strives because the energy is in him. But then there may be something more. One day when the air brakes had saved a train from disaster he said:

"If some day they say of me that with the air brake I contributed something to civilization, something to the safety of human life, it will be sufficient."

THE WORK OF THE ILLUMINATING ENGINEER[1]

By DONALD CAMERON SHAFER

"WE have made a new profession, that of illuminating engineering, but we are still very far from the perfect artificial light," remarked a well-known inventor. "Only a little while ago there were no men to specialize on artificial lighting. Such work was trusted to the architect, who did the best he could with his meager knowledge of the subject. To-day illuminating engineering is a recognized profession and to-morrow colleges will be granting degrees to new illuminating engineers. You smile, but I have helped to make professions before. I can well remember when we talked about electrical engineering as a profession, and people laughed in our faces. To-day there are thousands and thousands of electrical engineers. Long before we perfect artificial illumination the new profession will be recognized."

"Is there such a thing as a perfect source of artificial light?" asked one of his auditors.

"O yes, we already know of such a light. Almost everybody has seen this light, but all the wise heads in the world can not read this simple secret which Nature has seen fit to bestow upon her most lowly forms of animal life. Behind you sits a darkened cabinet; inside of it is a little box. Shake that box a bit and you will see the only perfect source of light known to man."

With eager faces the visitors crowded about the cabinet.

[1] By courtesy of "The American Review of Reviews." Copyright, 1909.

Then with the look of disappointment one turned toward the inventor with the remark:

"Why, there's nothing but glowworms and fireflies in that box!"

"Nothing but glowworms and fireflies," remarked the scientist, "and yet each one of those little creatures carries around a secret worth millions and millions of dollars. If I could discover that secret to-day, inside of a year I could make the fortunes made out of oil look like the widow's mite. For, do you know, each one of those fireflies and glowworms carries a tiny light which they turn on and off at will? This tiny light gives very little or no heat, whereas the best incandescent electric lamps we can make waste more than ninety per cent of the electrical energy in useless heat for what little light they give. Take that sixteen-candlepower lamp above you, for instance; it consumes fifty watts of electricity to produce sixteen candlepower of light. Only two watts of this go to make the light and forty-eight watts are wasted in heat. If I could reverse those conditions I could get twenty-four times as much light, or three hundred and eighty-four candlepower, from the same amount of current. Fireflies and glowworms know the secret of light without heat; man does not. But some day we shall read this puzzle, as we have read so many before, and the night will be as day. In the depths of the ocean even the penetrating light from the sun is barred, yet there is light, and electric light, too. Almost every one of these deep-sea creatures carries a tiny light similar to that of the firefly, — a light that can be turned on or off at will. We assume that the 'electricity' for this light is produced by nervous energy; beyond this we really know nothing.

"But with all this study and research, while the secret

remains unsolved, we have improved all the sources of artificial illumination and incidentally, as I said before, produced the illuminating engineer. Born of necessity and economy, it is a good thing the illuminating engineer is here, for we have been shamefully neglecting our health, eyesight, and pocketbooks ever since man first snatched a burning brand from the fire and lighted the way into his cave."

The elder Agassiz, the famous Swiss scientist, once remarked that every great invention, every new thing, had to pass through three stages of development: first, when everybody said it was impossible; second, when it was thought contrary to religion; and third, when everybody said it was known before. Illuminating engineering has already passed the first stage and is well on its way toward the end of the second, where very little murmuring is heard against the new branch of applied science, so opposed to the ancient dogmas and creeds of the commercial world.

All engineering involves questions of economy, and the best engineering practice is that which accomplishes the best results at the least cost. When the mining industry demanded men to make a systematic study of geology and minerals, so that they might be of value to their employers in keeping them from wasting money on worthless claims, the mining engineer sprang into being. When the cry for electrical inventors rang over the world, men began to study and investigate this branch of science, and the electrical engineer came into his own. Giant bridges and lofty buildings, continental railroads and water-power developments demanded civil engineers, and even the great industries have produced their mechanical engineers.

While this new profession is distinctly American it

is true that the pioneer work was started in England when Mr. A. P. Trotter developed several new methods of calculating illumination and advocated a more rational use of light. But from this humble start Americans made this new profession. Illuminating engineering belongs to this country, and the veterans in the profession can be counted on the two hands. Ten years ago the infant had not even been christened, and the rapidity with which this science has been accepted and placed among established professions has no parallel in history. After centuries of ignorance, prejudice, and malpractice, in the short space of half a dozen years illuminating engineering has risen to a position of recognized standing and independence.

Light travels at the incomprehensible speed of one hundred and eighty-six thousand miles a second. This is equally as fast as electricity travels and is so nearly instantaneous that the most delicate machines are necessary to measure it. But, swift as it is, light and illumination, though intangible, can be definitely measured. The laws of light, too, are well understood and are comparatively simple.

The source of light (except that of the glowworm and the firefly) is a substance which is raised to such a temperature that it sets up waves in the surrounding ether, which, when falling upon the eye, produce the sensation we know as light. It is acknowledged that the source of light in the sun is a great mass of white-hot matter. The source of light in an arc lamp is the heated particles of carbon floating between the white-hot tips of the electrodes, which are raised to a high temperature by electricity. In an incandescent lamp the light source is a thin filament maintained at a high temperature inside the glass globe by the passage of a current of electricity.

In gas and oil lamps the light is thrown off by the myriad particles of carbon heated to incandescence in the flame. In the new gas lamps it is the white-hot mantle which produces the light.

The human eye can withstand ordinarily, without fatigue, a brilliancy of about five candlepower per square inch of surface. The intensity of light sources ranges all the way from the two or three candlepower per square inch in the ordinary candle flame to six hundred thousand candlepower of the sun when at zenith. This means that a square inch of candle flame gives off from three to four candlepower, while every square inch of the sun's surface gives six hundred thousand candlepower. The intensity of the arc light ranks next to that of actual sunlight, being about ten hundred thousand candlepower per square inch. The new metal filament lamps give about one thousand candlepower, which means that if we had a ball of tungsten as big as the sun, heated by electricity, it would throw off a thousand candlepower of light for every square inch of its surface.

By means of a refraction prism a beam of light may be separated into the various colors of which it is composed. White light, for example, is composed of all the colors of the rainbow harmoniously blended together. The sun, high in the sky, gives a pure white light; the arc and metal filament electric lamps give a light that is very nearly pure white; the light from the mantle burner is greenish white; sky light is bluish white; the kerosene lamp gives an orange light; the open gas flame is yellow; the candle produces an orange-yellow light. This difference in the quality of light depends on the difference in temperature at which the heated elements operate.

The fusing point of tungsten (three thousand and fifty degrees Centigrade) is higher than that of any other

known metal, and enables it to operate at the very high efficiency obtained in the tungsten lamp. One of the laws of incandescent light is that the higher the temperature the better the light and the greater the economy of current consumed. Up to a few years ago tungsten was known only in laboratories, and then only in a very impure state, and on account of its rarity the price was very high. But latter-day prospecting has resulted in the finding of vast bodies of the ore, and the price has correspondingly dropped to about seven dollars a pound. It would be even lower than this but for the difficulties in refining the metal. Only with the electric furnace is it possible to produce tungsten in its pure form. Pure tungsten is hard enough to scratch glass; it is almost impossible to melt it; it is malleable to some extent, but not ductile. Because it can not be drawn into wire the wire-like filaments employed in the electric lamps are made by a commercialized laboratory process.

These new tungsten incandescent lamps, with the same consumption of energy and expense to the consumer for current, give nearly three times the illumination of the old carbon lamps. The lighting companies were quick to see the advantages of this wonderful improvement, and are now encouraging their customers to use the new lamps, making it plain to them that they can obtain three times as much light of a better quality for the same money.

To those whose homes and business places were already abundantly lighted it was apparent that the new lamps would easily give the same light as the common incandescent lamps for one-third the cost. A home that was lighted by electricity for two dollars and thirty-five cents a month could be lighted with the new lamps for seventy-eight cents. Not only that, but the light from the new

tungsten lamps proved to be nearly pure white, akin to actual sunshine, soft, pleasing, and beneficial to the eyes, and not of a yellow cast like the common incandescent lamps.

Within the past few months tungsten has revolutionized the electric-lighting world, and has proved the greatest boon to the consumers of electric light since the discovery of the incandescent lamp.

Fully to understand light one has to assume the presence of a wave motion set up and maintained by the source itself. The color of the light depends on the length of the wave. The light waves producing the colors in the blue end of the spectrum are very short compared with those that produce the colors near the red end. The light source which we know as red gives off only waves of the length that produce that particular color. A body appears red because its surface is capable of reflecting only waves of lengths corresponding to red. If an attempt is made to illuminate a blue body by a red source it will fail, because the blue body is capable of reflecting only the short waves producing the blue, and since the red source contains none of these there will be no reflection and the body will appear black. In the dark there is no color. We see objects by the light reflected from them. In department stores white goods are often displayed on the same floor as dark woolen goods. In this case, if the intensity of the light is the same throughout the store, the section containing the dark goods will appear poorly lighted as compared to the section containing the white, because black absorbs light, while white reflects it.

If we attempt to transmit white light through a red glass only the red rays will be transmitted, the others being absorbed by the glass. Instead of getting all the

energy of the light we get only that part included in the red ray.

It was formerly the custom to blame the oil, or the gas, or the electricity if there were dark shadows in the room or if the light failed to dispel the evening darkness. Now the illuminating engineer has proved that these same rooms, be it at the home, or the office, or the store, can be made almost as light as day with even less candlepower than before, all with a little study and planning.

The first duty of the illuminating engineer was to bring about an important change in the practice of placing the lamps. This was very hard to do because the antiquated chandelier had become a habit with architects and builders. Only after the engineer had repeatedly proved that better illumination could be secured by using several lights distributed about the apartment was this change brought about. Now, when an engineer is asked to figure on the artificial lighting of a building the first thing he does is to get the dimensions of the rooms and the color of the walls, ceilings, floors, and furniture. Then he ascertains the exact amount of light required for each apartment, and figures out the "wattage" necessary to secure the desired illumination. Once he knows the "wattage" it is easy to figure out the number of lamps required, the candlepower of each lamp, and the proper places to arrange them on the ceiling to get the right effect.

The matter of proper shades and reflectors has also been carefully investigated by the engineer, with the result that many of the old types have been thrown on the junk heap and new and better ones devised on scientific lines. These new reflectors concentrate, diffuse, or focus the light to meet the demands of the lighting speci-

fications, utilizing the new illuminants to the best advantage.

One of the greatest feats of illuminating engineering was the night illumination of Niagara Falls during the summer of 1907. Successfully to illuminate this mighty torrent a battery of nearly fifty large searchlights, several of them the largest of their kind and capable of throwing a beam of white light one hundred and twenty-five miles, was located below the falls. Some of these searchlights were placed at the water's edge opposite Goat Island and others on the cliff, both on the Canadian side. This arrangement permitted the illumination of both the Canadian and American falls and threw a plunging light on the falling water and flying mist. The light from the battery of searchlights, when thrown into the sky, could be seen as far away as Toronto and Rochester.

The tower of the Singer Building in New York is another triumph of the new illuminating engineer. This tower is also illuminated nightly by powerful searchlights.

Among the greatest achievements of the new profession has been the illuminating of the great expositions. While the Pan-American Exposition at Buffalo was undoubtedly the best example of scenic lighting, the Seattle exposition was a close second.

In a certain rifle factory every method was tried for artificially lighting the rifle range, but without success. As soon as the sun began to sink into the west the testing of the rifles had to stop. An illuminating engineer was sent for, and after carefully measuring the amount of daylight on the target at all hours of the day he devised a special arrangement of the lighting source which worked so well that the marksmen pulled down the curtains by day, preferring to shoot under the artificial light

rather than the light from the sun, which varied every time a cloud passed over its surface.

The artificial illumination of the new union station at Washington, D. C., is perhaps the finest example of the illuminating engineer's work in the country. This station is lighted indirectly by electricity after the most scientific and approved methods. Not long after it was installed a man and his wife from Milwaukee had occasion to spend several hours in this station waiting for a train. The husband was an official in an illuminating company and had made more or less a study of lighting. After a time the wife went out on the street and did not return for some little time. "I 'm glad to get back safely, John," said she, "for it's so awfully dark outside."

"Dark? Why, no, it is n't dark yet. It 's as light as can be," answered the husband.

Nor would the husband believe it was dark until he went outdoors himself and looked. Much to his surprise it was as dark as pitch out of doors, yet the illumination of the station's interior to all appearance had not changed at all in the transition from day to night.

The illumination of this station is ideal from the engineering point of view. Artificial illumination, to be correct, should diffuse the light in exactly the same proportion as actual daylight, and the light source should approach the exact color of sunlight as nearly as possible.

The terms used by the illuminating engineer are easily understood. Candlepower, as its name implies, means the intensity of light given by a single sperm candle. The term "foot-candle" is the intensity of illumination a single candle gives on a screen one foot from the flame.

The luximeter, the latest instrument to be devised by the illuminating engineer, is a portable device for measuring the illumination on any surface.

The luminometer, or type-reading photometer, is used for measuring the lighting distance or illuminating value of street lamps.

The spectroscope and spectrophotometer enable us to analyze a beam of light and measure the colors. With the spectrometer the scientist can tell from a ray of light whether a star is moving toward the earth or away from it, and how fast.

There is also a large variety of photometers for measuring the candlepower of different sources of light.

Not two hundred years ago Broadway, New York, after nightfall was almost pitch dark and infested with rogues and thieves. It was not safe to travel it by night without armed guards and boys carrying torches. To-day this great thoroughfare is famous as the "Great White Way" because of the brilliancy of its night illumination.

Seventy-five years ago streets were lighted with oil and gas. Twenty-five years ago the electric lights were introduced and the systematic lighting of streets began; now there is scarcely a hamlet so small it can not boast of lighted streets. And the men who are studying the subject say that the dawn of artificial light is just breaking.

SELDEN'S EXPLOSION BUGGY[1]

By LEROY SCOTT

THIRTY years ago, a young man with a scheme for a carriage to be run by a gasoline motor, called upon a large manufacturer of vehicles and farm implements. The young man had spent years upon his patent — its success meant fortune to him, and also triumph over the men who had laughed at him. So he used his best eloquence to induce the manufacturer to put his automobile on the market.

But the manufacturer shook his head. "You've been wasting your time on that scheme," he said. "And if I went into it, I should be wasting my money. No, sir — even if it worked, nobody 'd ever care to ride in your 'explosion buggy.'"

The young man was George B. Selden, and what this manufacturer said was also said by dozens of others. To-day there are in use in the United States about seventy-thousand "explosion buggies"; and about seventy per cent of all gasoline automobiles made in this country or imported into it are licensed under the Selden patent — the patent, that in the late seventies and during the eighties, manufacturers smiled at as the impracticable scheme of a dreamer.

Seated in the machine shop on the third floor of his home in Rochester, New York, with lathes and batteries and tools about him, and before the original engine, Mr. Selden related the story of the development of his invention and his long struggle to get it on the market.

[1] By courtesy of The Technical World Company. Copyright, 1906.

Mr. Selden is a gray-haired man with a strong chin that clenched tightly when he spoke of the jeers he had endured, and with quick eyes that gleamed like steel points when he spoke of his ultimate triumphs. He is intensely himself — defiantly himself. The things he believes, he believes with his whole being; once his heavy jaw sets, all the world can not change him. And he has needed this self-confidence, this aggressive, dogged determination; without them he could never have kept on during the years that discouragement and poverty sought to make him abandon his invention.

When Mr. Selden was a boy of about fourteen, he chanced to hear a conversation between his father — who, though a lawyer, was versed in mechanical things — and a manufacturer of farm implements, about self-propelled vehicles for public roads. They both agreed that such vehicles were impracticable. This discussion was to Mr. Selden what the spoon over the teakettle's spout was to James Watt — it started him thinking upon the subject that was to be the main theme of his life.

When he entered Yale in 1865 he attempted to do some reading upon the subject, but found few books treating of vehicles driven by their own power. Mr. Selden's career in Yale, from the academic standpoint, was not successful; he rebelled against his classical studies; and (so at least he declares) the only good recitations he made was when he was asked something not in the textbooks. This youthful revolt against academic requirements had its logical result in his attitude as a father: his two sons, now young men, have been almost wholly educated at home, where they were required to study only such subjects as fitted their bents.

Mr. Selden left Yale in 1869 and began the study of law with his father. In 1871 he was admitted to the

bar. Since 1876 his legal work has been entirely in the field of patent litigation. Despite the fact that his father discouraged his mechanical pursuits, desiring him to give himself wholly to the law, he continued his mechanical investigations in the leisure the law allowed him. Whenever he could get away from his office he would lock himself in his shop (he has always had a machine shop in his home) and ponder over mechanical problems or make experiments.

His first investigations had in view the development of the steam automobile, which during the twenties and thirties of last century seemed to have such a brilliant future. In March, 1873, he abandoned steam as the power for a road locomotive and began the study of engines using other agents. He investigated engines to be operated by ammonia gas, by bisulphide of carbon and other liquid fuels. In 1874 or 1875 he built and operated an engine that was driven by a mixture of "laughing gas" and kerosene. The mixture was burned in a small chamber and the expanded products of combustion were fed to an engine similar to the ordinary steam engine. But, owing to the internal corrosion of the engine by the mixture, this machine soon proved to be a failure.

Mr. Selden was greatly hampered by the fact that his law practice, not very remunerative at this time, had to support both his family and his experiments, with the consequence that the latter had to be conducted upon a stringently economical basis; and by the further fact that, at the beginning of his investigation, he had no information whatever about liquid-fuel or internal-combustion engines, and had to gain it almost entirely from his own experiments. He was exploring what to him was an unknown territory. So he moved slowly, often taking

the wrong direction, often halted by seemingly insurmountable difficulties. But by 1876 he had reached the conclusion that road locomotion would be achieved only by an internal-combustion engine of the compression type using liquid fuel, most likely one of the lighter petroleum products. At last he was on the right road.

Thirty years ago Mr. Selden never dreamed of the automobile of the present — of a touring car that would run thirty, forty or fifty miles an hour, of a racing machine that would run two miles a minute. His dream was of a light carriage that would run as fast the second or third hour as a good horse would the first — ten miles an hour. Fully to understand the task he was attacking, it must be remembered that the Lenoir gas engine of this period weighed about five thousand pounds per horse power, the flywheel being as heavy as an ordinary touring car, and that the Otto engine of a few years later weighed per horse power about fifteen hundred pounds. After Mr. Selden gained the basic idea of his engine there followed a year of thought and experiment. He had many black days. In October, 1877, he wrote in his diary, "Can't carry on about a dozen patent law suits and do much experimenting at the same time." And the next day he wrote, "If ever I get a road wagon it will be by accident. Of the almighty effort which an invention requires, who knows but the inventor?"

But he kept indomitably on through these periods of depression, and by the latter part of 1877 he felt he had conquered, either by actual experiment or by theory, all his main problems. The time had come to build the engine.

Meanwhile people had continued to sneer at Mr. Selden. His own brother advised him to go no further, and told him he might as well throw his dollars into the

river. The draughtsman who made the drawings of the engine under Mr. Selden's direction (Mr. Selden was not then a practical designer of machinery), laughed at the specifications as he drew them and openly said Mr. Selden was spending money like a fool. But Mr. Selden's faith in his idea carried him on; the specifications, then the patterns, then the castings, were made. At this stage he felt, with especial keenness, the lack of money, which had all along crippled him. His compressed-air chambers were sections of boiler pipes, his flywheel he picked up at second hand in a foundry, a few parts not essential to the demonstration of the running ability of the engine were omitted, and only one of the three cylinders was fitted up. At length, early in 1878, Mr. Selden's long dream stood before him in steel and brass.

Would the engine run? Would his friends and enemies still have occasion to laugh at him, or would it be his turn to laugh? The May day in 1878 when the first test was made will forever be to Mr. Selden an unforgetable day. The trial took place in the corner of a foundry boarded off into a small room. All was made ready — the ignition flame was lighted — the flywheel given a turn. There was a sharp explosion, then increasingly rapid explosions. The engine ran!

The gasoline motor has developed marvelously in the years that have since elapsed; yet nevertheless the operation of this pioneer engine will always be of interest.

It was almost a year before Mr. Selden could spare the money necessary to file an application for a patent. The chief claim of the application, which was filed May 8, 1879, is as follows:

"The combination with a road locomotive, provided with a suitable running gear including a propelling wheel and steering mechanism, of a liquid hydrocarbon gas

engine of the compression type, comprising one or more power cylinders, a suitable liquid-fuel receptacle, a power shaft connected with and arranged to run faster than the propelling wheel, an intermediate clutch or disconnecting device and a suitable carriage body adapted to the conveyance of persons or goods, substantially as described."

Owing to the delays natural to the prosecution of an application, the patent was not granted till November 5, 1895.

Eighteen seventy-eight and seventy-nine were hard years with Mr. Selden — as were many before and many after. He was financially unable to build the running gear and so complete his "gasoline buggy." But in constructing a light engine that would run he believed he had solved the problem of the automobile, and he hopefully began to try to interest capital in his invention. But he quickly found that the efforts required to evolve his invention were nothing compared to the efforts required to get it on the market. He was dealing with a new power; the public, and even manufacturers, could not understand what went on inside the engine, consequently had no confidence in it.

Mr. Selden tried to interest almost every client he had in the invention; he laid it before dozens of firms manufacturing carriages and agricultural implements. Two men to whom he offered a half interest in his patent for a very meager consideration, rejected the offer with contempt and expressed pity for Mr. Selden's family. They classed Mr. Selden — and so did hundreds of others — with the crack-brained pursuer of perpetual motion. Some of the manufacturers declared that the invention was not operable; some that, even if the machine would run successfully, it would be of value merely as a curi-

osity — no sane human being would care to go bumping along upon a sort of rapid-fire gun. Of all the men he wrote to and interviewed, only two gave him genuine encouragement. With both men he made, at different times, a conditional arrangement for the manufacture of his self-moving carriage. In each case he thought success, recognition, were coming at last. But fate was still against him. Before operations could be begun, one man failed, the other died.

But success and prosperity were awaiting Mr. Selden. When Daimler and Benz (who began their automobile experiments about 1885, and who are credited with being the fathers of the automobile revival in Europe) and other European inventors had proved that the gasoline motor was not only practical but had a great commercial future, American manufacturers began to awaken.

The beginning of this interest came about 1893; but not till 1896 was the first American-made automobile put on the market, and not till 1899, when there were in the United States only fifty automobiles, did the interest begin to have any volume. Mr. Selden now found a very different attitude toward his patent. In 1899, twenty years after his invention had begun to beg for recognition, he entered into a contract with an old and prominent Eastern automobile company. This contract licensed the company in question to manufacture automobiles under the Selden patent, and granted the company power to issue sub-licenses to other manufacturers.

A considerable number of American manufacturers have refused to take out licenses under the Selden patent, their contention being that their automobiles are not infringements of Mr. Selden's invention. Mr. Selden's claim, of course, is that his patent is the basis of the modern gasoline automobile.

A few years ago Mr. Selden had his 1878 engine fitted up and mounted on a carriage, the work all being done in accord with the specifications of the patent application of 1879. This automobile is now in frequent use. It weighs about seven hundred pounds, and can carry three persons at a speed of about eleven miles an hour.

Mr. Selden's activity as an inventor has not been limited to the field of the self-propelling vehicle, though of course the automobile has been the supreme interest of his inventional career. He has invented a hard rubber tire, a traction device to prevent the slipping of wheels, improvements on a hoop-splitting machine, a power-driven typewriter, and several other devices. He and his two sons, both of whom are inventors, are at present engaged upon inventions which aim to improve certain details of the present-day automobile.

Mr. Selden's financial reward was a long time in coming, but now that it has come it is a most gratifying one. The royalty on all automobiles manufactured and imported under the Selden patent is one and one-fourth per cent of the list price, and of this Mr. Selden gets a substantial share.

THOMAS ALVA EDISON

BY GEORGE ILES

THOMAS ALVA EDISON, great as an inventor, is remarkably simple as a man. His massive head, square jaw, and virile stride are those of a born conqueror, let him have chosen what path he might. At the base of his victories stands a physical vigor that laughs at fatigue, that finds him at sixty a boy in lightness of heart, in love of fun. He hopes for at least thirty years more of hard work; his father lived to be ninety-four, and his grandfather to one hundred and three. Two of the best strains in the world meet in his blood. His father, of Dutch stock, was born in Digby, Nova Scotia; his mother, Nancy Elliot, a native of Ohio, was of Scottish descent. At Milan, Ohio, on February 11, 1847, their famous son was born. His father was so poor that the boy went to school for only two months. But his mother, who had been a school teacher, taught him all she knew; and her lessons were the best he ever learned, for they put him in the way to instruct himself. For all the narrowness of his early circumstances, Edison has acquired an informal education both wide and thorough. He knows supremely well how to think, how to work, how to express himself with clearness and precision.

When he was seven years old his parents removed to Port Huron, Michigan, where five years afterwards he began to earn his bread as a newsboy on the Grand

[1] By permission of the author. From "The Chautauquan." Copyright, 1908.

Trunk Railroad. One day at Mount Clements, a station on the line, an act of bravery proved the turning point in his career. He saw the station master's child playing on the track, while a train rapidly approached. In a flash, at the risk of his life, and not a moment too soon, Edison plucked the child to safety. Its father, Mr. J. U. Mackenzie, as a mark of gratitude, taught Edison telegraphy, and thus introduced him to the world of electric art in which he has become illustrious. As an aid in learning how to work a key, Edison built a telegraph instrument with his own hands in a Detroit gunshop. It was rough and clumsy, but it served, and that was all he wanted.

Thus early did he manifest that skill of hand without which there can be no inventor. And as he put together key and lever, a spring and a rudely wound electromagnet, he came to understand how a telegraph instrument does its work. He discovered what a "circuit" is, what "polarities" mean; he gained a first-hand acquaintance with batteries, much more troublesome then than now. Principles, as well as patterns, then and there began to impress that extraordinary intelligence.

His resourcefulness, too, was soon displayed. One morning, in April, an ice jam snapped the cable between the shores of Port Huron and Sarnia, divided by the St. Clair River, here a mile or more in width. Telegraphy was suspended, and the railroad people were at their wit's end. But Edison was far from being at the end of his wits. He jumped aboard a locomotive, manipulated its whistle with the long and short signals of the Morse alphabet, and in two minutes, by attracting the attention of the Sarnia operator, messages were exchanged across the ice-floes. Edison is wont to recall this as his first feat in wireless telegraphy.

We find him next at Stratford, Ontario, a night operator on the Grand Trunk Line. To keep tab on him the local agent required "six" to be ticked off on his instrument every half hour. Edison deemed this attendance quite needless; accordingly he notched a wheel so that every thirty minutes it set off the six dots demanded. That wheel was afterward developed into the "call" of the district telegraph systems. In those days, more commonly than now, telegraph operators were a roving tribe, and, in the course of a wide pilgrimage, Edison at seventeen was working a key at Indianapolis. Here he devised his automatic repeater, which takes an electric pulse as it arrives faint and feeble at the end of a long journey, and makes it touch off a strong local current which wings the message for a second lengthy flight.

Taking to the road once again, Edison in 1868 found himself in Boston. He had now become so expert that, when he wrote his smallest hand, he could receive fifty-four words a minute. During this stay in Boston he invented his electrical vote-recorder, on which, at twenty-one, he secured his first patent. This apparatus recorded and summed ayes and noes exactly at once. Yet it was declined, with thanks, by the Legislature of Massachusetts. Its inventor, bitterly disappointed, believed that this "No" was voted because his mechanism threatened to put an end to filibustering, a process in which legislators then, and afterward, have found advantage. Ever since, in aught but experiments undertaken solely for inquiry's sake, Edison has always ascertained that there is a market for an invention before he seeks to give it substance and form.

At this period of his career, the committal of two or more messages at a time to a wire was enlisting the skill of many ingenious men. "Why should n't I try, too?"

asked Edison. At the end of many toilsome experiments he came to two distinct plans for sending two telegrams simultaneously over a wire. Then, uniting both methods, he created his quadruplex system, enabling four operators to work one wire at once. This apparatus was installed by the Western Union Company, and forthwith began saving no less than six hundred thousand dollars a year. Devices much less important, and incomparably more simple, excited Edison's passion for improvement, for thorough reconstruction. He examined a round of telegraphic printers, found them all imperfect in design and liable to derangement under stress. This, especially in stock-exchange service, was a serious matter. He designed a new automatic printer, so effective that it is at work to-day, little changed after thirty years' good service.

With capital earned by his patents, Edison, in 1873, established at Newark a factory for the manufacture of his inventions, for experiments of a new breadth and boldness. Thus, at twenty-six, to what he could build with his own hands was joined what could be made by the hands of other skillful men, under his direction. From that day to this, Edison's method has been that of a general in the field. First he conceives an idea for a new device or process, and thoroughly informs himself as to its feasibility. He then engages the mechanics and engineers, the physicists, chemists, or mathematicians required to aid him in attack. From stage to stage of experiment he and his staff are in conference. With no regard to cost or trouble he moves steadily to victory, or comes to clear proof that an attempted battle is not worth winning.

Among the successes thus achieved is the phonograph, which Edison considers his chief creation. It came as

the logical result of his automatic recorder of telegrams. He says:

"In 1877 I had worked out satisfactorily an instrument which would not only record telegrams by indenting a strip of paper with dots and dashes of the Morse code, but would also repeat a message any number of times at any rate of speed required. I was then experimenting with the telephone also, and my mind was filled with theories of sound vibrations and their transmission by diaphragms. Naturally enough, the idea occurred to me: If the indentations on paper could be made to give forth the click of the instrument, why should not the vibrations of a diaphragm be recorded and similarly reproduced?

"I rigged up an instrument hastily, and pulled a strip of paper through it, at the same time shouting, 'Hallo.' Then the paper was pulled through again, my friend, Batchelor, and I listening breathlessly. We heard a distinct sound, which a strong imagination might have translated into the original 'Hallo.'"

Long before that memorable day Scott, and other inventors, had coated glass or metal plates with lampblack, and there obliged sound-waves to trace their paths. Edison adopted yielding paper, and there bade these waves dig a channel, instead of merely marking a superficial line. That channel became a means of repeating every sound-wave that had been said or sung in to the paper. Of course, at first this echo was muffled and uncertain. Results were much better when tinfoil took the place of paper. To-day, at the end of many improvements, the impressed cylinder is of wax: in a length of six inches it receives twelve hundred words from a sapphire point vibrating from a mica diaphragm. Every syllable and tone is reproduced with marvelous verity

and fullness as another sapphire, tipped as a ball, runs along the waxen channel, vibrating a thin, corrugated diaphragm of copper. In its present form this instrument is in wide and growing use for business correspondence. A merchant, a banker, speaks into its tube at his convenience. A clerk, at a second and reproducing machine, afterward listens to the record and typewrites it for the post office. In education the phonograph is just as valuable. It utters words, in English or other tongues, for the behoof of students; it repeats, as often as desired, a lesson in engineering or other science. Could scholars but agree on a standard pronunciation of the English language, the phonograph stands ready to give them a means of unvarying reference for future years.

Next to the phonograph in Edison's honor roll comes his incandescent lamp. This invention most severely tested his courage and endurance, his unmatched suggestiveness of mind. In October, 1879, after repeated failures, he produced a lamp that lasted longer than a single day, assuring him that success lay within his grasp. From comparing threads of many kinds he felt certain that a vegetable fiber, duly treated, would be the best light-giver. He accordingly despatched William Moore to China and Japan in quest of every promising variety of bamboo. From these he chose a filament uniform in quality and fairly durable. Art followed nature. Further investigation showed that cellulose squirted through a tiny orifice, and suitably treated, was preferable to bamboo. That his lamp might become popular, many accessories were required. Edison provided an electrical generator, and a three-wire mode of transmission which greatly reduced the amount of needed copper. He adopted and improved new methods of exhausting his bulbs, of introducing their platinum wires, of sealing and testing

each lamp for service. He mapped electric lighting as a whole, and supplied every detailed need with unfailing originality. To-day his lamp is undergoing eclipse because tungsten glows more brightly and cheaply than carbon. But in the history of illumination Edison has written a noble chapter. Those who now go beyond him do so because he broke ground for them and made straight their paths.

As far back as 1883 Edison began applying electricity to transportation. His first locomotive is perhaps the most uncouth model that ever left his shops; and yet it ran at a lively speed around his experimental track. The field was entered by other inventors and Edison, drawn away by tasks that promised better rewards, is not among the men who have created electric railroading. But for years past he has worked at a storage battery to propel road vehicles cheaply and well, with the minimum of weight. Never has he faced a tougher problem. We enter his laboratory at Orange: there is a zinc rod, let us say, dissolving in an acid solution, and yielding an electric current. Near by is a plating tank, where a second zinc rod is being deposited from a solution, by virtue of just such a current as that flowing from the first rod.

It would seem easy for such a man as Edison to contrive a cell which should first dissolve a metal and give forth a current, then redeposit that metal as a like current enters its solution. But the two processes, simple though they appear, are intricate in the extreme; they do not match each other at all. We can readily freeze water, and as readily thaw the resulting ice in a direct reversal. Chemical energy, however, does not move in straight lines of this kind, but in labyrinths to be threaded only in one direction.

To offer a homely comparison: a very little heat will

fry an egg, but what Arctic cold could unfry that egg and restore its complex albumens to their first estate? Last October when I called on Mr. Edison I found him busy in experiments on his new storage cells. He had been using cobalt and nickel-iron, immersed in an alkaline liquid. Cobalt had risen to a prohibitory price, so he was testing a substitute, excellent in promise. He said:

"These new cells will weigh fifty-three pounds for each horse power developed one hour; so that a battery of five hundred and thirty pounds will afford two horse power for five hours, or any equivalent desired. Just when nobody uses an electric truck or runabout, say betwixt midnight and six in the morning, power houses have nothing to do and are glad to re-charge vehicle batteries at low prices. Thus a user all day virtually draws upon a central station as cheaply as if he were connected with it by a trolley wire. I expect my new batteries to run as long as thirty thousand hours before they need be thrown away."

Edison's career has not been a series of unbroken triumphs. Many a model, a child of hope and promise, has he at last had to fling on the scrapheap. In one notable case he has turned a failure to a handsome profit. Close to his laboratory is his factory for phonographs. This huge building, floored, walled and roofed in concrete, is as much a unit as if it were a single brick without seam or chink. It stands a monument to a victory born of defeat. Near Edison's home in New Jersey are vast deposits of iron. These are so abundant that though thin in metal he decided, about ten years ago, to begin their reduction. He straightway invented pulverizers of new effectiveness. Their streams of dust were let fall close to powerful magnets; these deflected the iron particles just enough to

bring them into a chute of their own. But Edison had not reckoned with the rich ores of the Mesaba range, easily excavated from surface deposits at a few cents a ton. Did he, in despair, cast his pulverizers into the melting pot? No. He bade them grind cement into so fine a powder that it produces a concrete of unsurpassed strength. He shows, in a large model, a well-designed villa which may be cheaply duplicated a thousand times from metal patterns. Its concrete may be readily poured and finished within but twelve hours.

This man is much more than a great inventor. As far as mortal can, he keeps abreast with the swift strides of science, physical and chemical, botanical and medical. Two years ago, when I paid him my respects, he pointed to a group of radio-active minerals placed on photographic paper.

"This radium is giving old-fashioned ideas a knock, is n't it? Here is an element that changes its identity, shatters each of its atoms into a thousand fragments, and stays two degrees warmer than its surroundings all the time. Talk about coming to the limits of knowledge! Why, we are scarcely on the threshold; we 've just begun to suspect a few things, that 's all!"

Last October, when I told him that I had just seen beautiful photographs in natural colors in the new Lumière plates, he said: "I want a dozen of those plates for experiment as soon as Lumière can send them. I wonder how red will come out of them. Red has always given most trouble in color photography."

A totally different field of labor has his keenest interest and sympathy. There is probably no one in America, outside of the medical profession, who more closely follows the work of the great physicians, in banishing with vaccines and antitoxins malaria and typhoid,

consumption and cancer. And how does he find time for all this reading of books, technical papers, "proceedings," so repellent to ordinary men? For such leisure as he enjoys he has to thank his deafness. He is so cheery and lovable, so fascinating a talker, that were his hearing normal, his friends would never for a moment let him sink into his reading chair. But debarred from all society but that of his family, denied the theater, the concert room, and the lecture hall, he reads as if he were a student working for an examination.

THE MODERN PROFESSION OF INVENTING[1]

By FRENCH STROTHER

THE complicated machinery of modern business has produced two types of inventor. One is the free lance, energetic and ingenious enough to create marketable inventions sufficient to maintain his financial independence. The other is the "inventions department," the idea factory or inventive brain of a great business, made up of a number of unknown units — men who have enough ingenuity and enough ideas to hold a salaried position as part of the creative organization of a manufacturing company.

The best-known example of the independent inventor is Mr. Thomas A. Edison. This strange man, so simple in personal appearance and manner, so extraordinary in his habits of life and methods of work, moves among his complicated series of shops and experiments with such mental precision and constructive energy, yet appearing to do so without any sense of order or system, — a sort of volcanic intellectual chaos, — that he is the despair of all the men who try to analyze him. But he has no sentimental notions about an invention. When an idea occurs to him his first question is, "If it can be done, is it worth anything?" If it will not pay, he has no use for it. Inventing is his business; the things he invents must be worth money.

The instant he decides that the idea is worth while he sets in motion his extraordinary method of developing it. Some time ago, for example, he needed a chemical

[1] From "The World's Work." Copyright, 1905.

mixture that should have two properties that are rarely found together in the same compound. He might have set a chemist to work to figure out from the known science of chemistry what would be most likely to fill the requirements, and so narrow the problem down to one of trying a few chemicals. What he did was to take Watts's Chemical Dictionary, in several ponderous volumes, and have his assistants make every chemical mixture in it that could even conceivably serve his purposes, and try every one of the thousands.

"Out of the lot I found about seven compounds that worked," said Mr. Edison, "but when I finished the experiments I knew beyond a doubt that those seven were the only ones that could be made for that purpose."

This, then, is his method — to take nothing for granted, to believe that anything may be possible, and then to try everything conceivable in the hope of hitting on what he needs. To see him moving through his great laboratories, head bowed, hands in pockets, his face set in an expression of intense mental preoccupation, his hair carelessly combed whichever way it may please to fall, his eyes focused miles away except when he flashes into some one else's a look of instant understanding, his whole appearance, except for the eyes and the humorous yet grim mouth, is that of a dreamer rather than of a tireless worker. Yet this is the man who, eating practically nothing and exercising not at all, works often for thirty-six hours without sleep, falls unconscious from exhaustion on bench or desk, and wakes to work again, sometimes for a week without undressing; electrical with mental energy; marvelous in the power of his inventive imagination. This is the popular idea of what an inventor is — a man of dreams and action in one, possessed by an idea that harasses him until it be delivered in finished form.

But inventors of this type form but a small part of the real profession of inventing. The great majority of practical inventions are made by a group of men of whom the public never hears. These men are members of one of the most complicated and highly organized of the modern professions. Every great manufacturing concern maintains, under one name or another, an "inventions department," employing men who are paid various salaries simply to develop inventions. They are supplied with every mechanical appliance to facilitate their work; the bills are paid by the company, and every invention they make is assigned to the company "in consideration of salary and one dollar."

The General Electric Company, at Schenectady, N. Y., for example, employs about eight hundred men who devote much of their time to developing new ideas. It spends two million five hundred thousand dollars a year in this development work. The Westinghouse Companies do the same thing; so does every progressive manufacturing concern of any consequence in the United States. And these unknown men, grappling with the everyday, practical problems of great manufactories, make most of the inventions of immediate commercial value.

Mr. Edison has very definite ideas about inventing as a profession. When asked to describe the personal qualifications and the type of mind necessary for an inventor, Mr. Edison said:

"The point in which I am different from most inventors is that I have, besides the usual inventor's make-up, the bump of practicality as a sort of appendix, the sense of the business, money value of an invention. O no, I didn't have it naturally. It was pounded into me by some pretty hard knocks. Most inventors who have

an idea never stop to think whether their invention will be salable when they get it made. Unless a man has plenty of money to throw away, he will find that making inventions is about the costliest amusement he can find. Commercial availability is the first thing to consider.

"In working out an invention, the most important quality is persistence. Nearly every man who develops a new idea works it up to a point where it looks impossible, and then he gets discouraged. That 's not the place to get discouraged, that 's the place to get interested. Hard work and forever sticking to a thing till it's done, are the main things an inventor needs. I can't recall a single problem in my life, of any sort, that I ever started on that I did n't solve, or prove that I could n't solve it. I never let up until I had done everything that I could think of, no matter how absurd it might seem, as a means to the end I was after. Take the problem of the best material for phonograph records. We started out using wax. That was too soft. Then we tried every kind of wax that is made, and every possible mixture of wax with hardening substances. We invented new waxes. There was something objectionable about all of them. Then somebody said something about soap. So we tried every kind of soap. That worked better, but it was n't what we wanted. I had seven men scouring India, China, Africa, everywhere, for new vegetable bases for new soaps. After five years we got what we wanted, and worked out the records that are in use to-day. They are made of soap — too hard to wash with and unlike any other in use, but soap just the same.

"The second quality of an inventor is imagination, because invention is a leap of the imagination from what is known to what has never been before.

Mechanical Designing

"The third essential is a logical mind that sees analogies."

Where a man in the profession of law or of medicine has a suite of offices, Mr. Edison's profession requires a great building containing many laboratories. In this building are rooms set apart for different kinds of experiments. In one, an assistant who came to him in 1889 from the laboratory of the German scientist, Helmholtz, works alone, or with his sub-assistants, on phonograph improvements. Mr. Edison may not see him for two weeks at a stretch, but when he does come he is full of enough ideas to keep that room busy for a month. In another room is his chief chemist, himself an inventor of proved merit, working out Mr. Edison's ideas on some new chemical compound. Across the hall, in a room filled with batteries, each of a different composition, two men and a boy are taking records of how the batteries work. In another room improvements are being worked out for Mr. Edison's new storage battery. There are often a dozen inventions under way at once, each requiring the work of an expert; and through the great laboratory Mr. Edison moves from room to room, keeping check on the progress of each, suggesting radical changes in the work, always full of ideas, and impressing so profoundly on his men his own mental curiosity, and eagerness, and energy, that they, as they say themselves, work much harder for him than they would on their own ideas.

Mr. Edison's power of rapid assimilation of the meat in any point discussed is one of the most valuable parts of his professional equipment. An instance, chosen from many of the kind illustrates how it serves him. On one occasion he started to study a part of the mechanism of typewriters.

"Have a model here next Tuesday of every typewriter made," he said to one of his assistants. "Have each company send an expert to explain their machine. And get me out all the books in the library about this piece of the mechanism."

Monday evening the assistant called Mr. Edison's attention to a stack of books several feet high and reminded him of the appointment next day.

"Send the books up to the house. I'll look them over to-night," said Mr. Edison.

The next morning he appeared at the exhibition, and so thoroughly had he read the books that he frequently corrected the experts' explanation of how their own machines worked. The assistant, out of curiosity, tried reading the references that Mr. Edison had absorbed in one evening, and it took all his spare hours for eleven days.

The results of Mr. Edison's professional activity as an inventor are about eight hundred patents allowed him by the Government. He takes out an average of one patent every two weeks. At present he is working out experiments with the chemicals used in batteries, improvements on his Portland cement, improvements on his storage battery, and a number of ideas that are not yet far enough developed to be published.

The inventions departments, the modern development of inventing, are maintained by the great manufacturing concerns. The National Cash Register Company, the Hoe Printing Press Company, the United Shoe Machinery Company, the Bell Telephone Company, and many others have each a corps of men who have displayed the inventive faculty, at work on salary developing the inventions needed by the companies. In any one of these departments new devices are being created that will not be made

public for years to come, because they are not yet perfected. The inventions by the time the public knows them are always months, and usually years, old.

The General Electric Company offers a typical example of the use of the inventions department. There are about fifty engineers at the head of various departments, and each of them is expected, as a part of his routine duty, to develop such improvements as are suggested by the needs of his department to keep it in a position to meet competition. Last year one thousand four hundred and twelve ideas were carried to the management by three hundred men as patentable inventions. Of these seven hundred and ninety-seven were found to be either impracticable or not new. The remaining six hundred and fifteen were developed by the company to such a degree of perfection that applications for patents were filed with the Patent Office at Washington. In round numbers, an average of five hundred patents a year are taken out by the company, every one of them for a device of immediate commercial value. To handle the legal end of the company's patent business, drawing up applications for patents, carrying them through the Patent Office, and conducting suits for infringement, a corps of twelve lawyers and twenty-eight assistants is maintained at Schenectady, besides two lawyers at Washington and one in Europe. These figures give some idea of the dignified proportions of the profession of inventing; for this company is only one of scores which carry on similar work on a greater or lesser scale. Follow one of the six hundred and fifteen inventions patented last year through all the stages of its development and consider what an inventions department means when that work is multiplied by six hundred and fifteen.

From the manager's idea to the completion of the first

commercial sample took six months; and from the completion of the sample to the time when the device was being manufactured in all sizes as a commercial product took two months more. To perfect the invention and carry it to the point where the first lots were put on sale cost the company four thousand dollars.

This matter of organization makes the inventions department a great institution. Mr. Charles P. Steinmetz, chief consulting engineer of the General Electric Company, whose genius is more for scientific and inventive work than for business, receives a very high salary as the chief adviser of the company in the practical development of inventions. His position and his financial success are possible only because he is an essential part of a great business organization.

In addition to developing practicable inventions, the company has maintained for five years, at an annual cost of about seventy-five thousand dollars, a laboratory of scientific research, in which many experiments are carried on that can have no commercial value for fifteen or twenty years to come. The dozen expert chemists who work under the direction of the chief chemist are all purely scientific men, not even engineers. They are not restricted in time, and carry on investigations in the unexplored regions of chemistry in the same spirit that Darwin carried on his investigations of the origin of species. The only way in which this laboratory can ever repay the company for its expense is by discovering such chemical compounds as are called for to perfect inventions, and by making discoveries of which practical use can be made in advance of other concerns.

From a business point of view, the maintenance of such a laboratory is at best an investment in the distant future, yet so inseparably has pure science come to be

a part of business that the company not only does not begrudge the present expense, but is constantly enlarging the scope and equipment of the laboratory, in the belief that it will ultimately pay for the original investment and be, besides, a source of great business strength.

In the case of the General Electric Company, the men are employed as engineers, as department heads, or in other positions involving routine duties; and their inventing, though it is expected of them, is in addition to their regular work. In many other companies, the inventions department is recruited from the sporadic inventors. They come from all businesses and professions. Some resign from the Patent Office to become inventors. One is an ex-newspaper man from the Middle West. Another was a groceryman in a small town in California. Another was once known as "The Lone Fisherman of Cape Cod."

The money return to a professional inventor in an inventions department is usually not large, but it is likely to be sure. The salaries paid range from the average two thousand dollars up to ten thousand or twelve thousand dollars a year. The inventions are assigned to the company employing him, though in rare instances a man receives a royalty in addition to his salary.

THE SIMPLE ORIGIN OF GREAT DISCOVERIES[1]

By IRA REMSEN

IMPORTANT results are often reached under what appear to be most unfavorable conditions, just as men of humble origin, with apparently everything against them, often accomplish things of which those more highly favored are incapable. Some of the most important discoveries in science have had humble beginnings; indeed, it is probably true that most important discoveries have depended very little upon elaborate and expensive apparatus and surroundings.

Not many years ago the laboratories in which students were trained and in which all scientific investigations were carried out were simply constructed and simply equipped, and every one who worked in them had to learn not only the principles of his subject but also how to help himself.

If he did not find exactly what he wanted ready for his use, he proceeded to make what he needed out of such simple materials as were at hand. He had to do this or fail. And it was the best kind of training.

But within recent years the palatial laboratory has come into vogue, and everything is supplied to the worker. This is not objectionable; in fact, it is highly desirable for those who have been well trained; but for students who are being trained it is most objectionable.

[1] By permission of the Author, "The Youth's Companion," and Ginn and Company. Copyright, 1908.

Some years ago the late General Armstrong of the Hampton Institute told the writer that the Indians who came to the institute were taught to take their baths in half-barrels and not in modern bathtubs, for the obvious reason that the half-barrel could be found in the home of the Indian, and the modern bathtub could not. That illustrates the principle. A student who has been accustomed to elaborate and expensive apparatus finds it difficult, if not impossible, to adapt himself to the simple things which he is likely to find when he goes out into the world to shift for himself.

A few illustrations taken from the history of chemistry and physics will show that great men have achieved great results with simple appliances.

The English chemist, Dalton, was a school teacher. He worked without a laboratory and with crude apparatus, mostly made by himself from simple materials. Here is an example described in his own words:

"Took an ale glass of a conical figure, two and a half inches in diameter and three inches deep; filled it with water that had been standing in the room, and consequently of the temperature of the air, nearly; put the bulb of the thermometer to the bottom of the glass, the scale being out of the water. Then, having marked the temperature, I put the red-hot tip of the poker half an inch deep in the water, holding it there steadily for half a minute; and as soon as it was withdrawn, I dipped the bulb of a sensible thermometer into the water, when it rose in a few seconds to one hundred and eighty degrees."

He then determined the temperature of the water at the bottom after five minutes, after twenty minutes, and after an hour, and found that it rose gradually from forty-seven to fifty-two degrees. This simple experiment proved that water has the power to conduct heat,

which had been denied by no less an authority than Rumford.

In much of his work Dalton used only a few vials and tubes with perforated corks, and frequently, instead of glass tubes, he used clay tobacco pipes with long stems. Such pipes, known as "churchwarden pipes," have been used by later workers, as notably in the remarkable work of Sir William Ramsay on argon.

As a grand result of his investigations on gases and liquids, Dalton gave the world the atomic theory, which has probably had a greater influence on the science of chemistry than any other theory that has been put forward.

This is not the place to discuss the atomic theory in detail. It will suffice to point out that it is a simple thought that helps chemists at every turn. It gave them a language that is intelligible, and suggested many important inquiries which in turn led to important experimental work. One biographer says, "Dalton's results stand out the greatest landmarks in our science (chemistry). . . . To him is due the glory of placing the science on a firmer basis."

Scheele was perhaps the greatest discoverer of facts the world has ever known. He was a Swede who lived during the latter half of the eighteenth century. Throughout his life he had to contend with sickness and poverty.

He was obliged to carry on the business of an apothecary on a small scale in order to keep the wolf from entering the house — he never succeeded in keeping it from the door. His great delight was to investigate things chemically and to find out all he could about them.

It is simply astounding to learn how many discoveries of the highest importance he made. The most important one was oxygen — a discovery that was made at the same time independently by the English clergyman, Priestley.

Oxygen was the most important single discovery ever made in the field of chemistry. It is the most widely distributed and most abundant substance in nature. It is necessary for the breathing of animals, and for most of the chemical changes that are taking place upon the earth. A knowledge of oxygen and of the ways in which it acts has done more than anything else to give chemists an insight into chemistry, and therefore has contributed more than anything else to the development of this science. Operations that had before appeared mysterious suddenly became clear, and every one engaged in chemical work was helped in many ways.

The discovery of oxygen has not only given us a broader and deeper knowledge of the earth and of the universe; it has also contributed largely to the material welfare of man — not directly, perhaps, but by enlarging his knowledge of chemistry, so that it may be said that most discoveries made since 1774 have been in a way consequences of the discovery of oxygen. Indirect results are often of more value than direct ones.

The moral of this story is found in the fact that this great discovery was made under the most unfavorable conditions, in a small apothecary shop, by a man in poor health who could provide himself with only the simplest apparatus.

But this is only one of many important discoveries made by Scheele. Another that may be mentioned here is that of chlorin. This discovery ranks with the most important and the most valuable of chemical discoveries. That of oxygen outranks it certainly, but it falls in line not far behind.

Why is it important? Primarily because it, like the discovery of oxygen, although to a less degree, aided chemists in their efforts to work out the problems of chemistry.

That statement may, once for all, be made of every important chemical discovery. But while Scheele had not thought of any practical uses to which chlorin could be put, it proved eventually to be of the highest practical value, and to-day it plays an exceedingly important part in practical affairs. It is the great bleacher, and as such is used in enormous quantities, especially for bleaching straw, paper, and different kinds of cloth. Then, too, it is one of the best disinfectants, and is contributing to our welfare by interfering with the spread of disease. Further, it is essential to the manufacture of chloroform, which is of such inestimable value as an alleviator of pain. And it is now used extensively for the purpose of extracting gold from its ores.

Compare the little room in the apothecary shop, the simple apparatus and the apparent uselessness of the noxious gas, with the great factories, the complicated machinery and the valuable applications. This discovery, like that of oxygen, was of humble birth.

Berzelius was another Swedish chemist who achieved great results with simple things. Early in the last century, while Dalton was working, and not long after the death of Scheele, he was engaged in important investigations, the results of which advanced chemistry greatly.

It is rather difficult to make his discoveries clear to those who are not chemists, but all chemists know that Berzelius was one of the great leaders in their science. Under what conditions did he work? We have an interesting description of his laboratory in a letter written by Wöhler, one of the greatest German chemists, who went to Berzelius in 1823 to study chemistry.

"With a beating heart," he says, "I stood before Berzelius's door and rang the bell. It was opened by a vigorous and portly man. This was Berzelius himself. As he led me

into his laboratory I was as in a dream, doubting if I could really be in the classical place which was the object of my aspirations. . . . I was then the only one in the laboratory. . . . The laboratory consisted of two ordinary rooms, furnished in the simplest possible way. There were no furnaces or draft places, neither gas nor water supply. In one of the rooms were two common deal tables. At one of these Berzelius worked, the other was intended for me. On the walls were a few cupboards for reagents; in the middle was a mercury trough, whilst the glass-blower's lamp stood on the hearth. In addition there was a sink with an earthenware cistern and tap standing over a wooden tub, where the despotic Anna, the cook, had daily to clean apparatus. . . . In the adjacent kitchen, in which Anna prepared the meals, was a small and seldom-used furnace and a never-cool sand bath."

This was the laboratory in which one of the greatest chemists did his magnificent work. Nothing could have been simpler. The work could not have been better.

Liebig became the leading chemist of the world, and yet he worked under as unfavorable conditions as Berzelius. When he began the study of chemistry there was not a laboratory in Germany. He tried to get the instruction he wanted, but had to go to France to get it, as Wöhler, also a German, had to go to Sweden.

Liebig tells us that when a boy he saw a man at a country fair make an explosive substance for crackers. He soon learned how to make this substance, and one of his first investigations was due to the suggestions that came to him at the fair. In fact, some of his most important work came from this humble beginning.

When he returned to Germany from France, at the age of twenty-one, he was appointed professor of chemistry in the little University of Giessen. There was no laboratory.

There was none in Germany, as has been said. He proceeded at once to get one. The first result of his efforts was a sorry affair — a barn without floor except such as was furnished by mother earth. There was no apparatus, nothing that we now regard as essential to a laboratory — except the enthusiastic leader.

In regard to this laboratory, one of Liebig's most distinguished pupils, the late Professor Hofmann of Berlin, wrote many years later:

"At the small University of Giessen, Liebig organized the first educational laboratory, properly so called, that was ever founded. The foundation of this school forms an epoch in the history of chemical science. Here experimental instruction, such as now prevails in our laboratories, received its earliest form and fashion; and if at the present moment we are proud of the magnificent temples raised to chemical science in all our schools and universities, let it never be forgotten that they all owe their origin to the prototype set up by Liebig."

Liebig had not only to fit up a laboratory with inadequate means and therefore with the simplest things, but he had to devise various forms of apparatus in order to carry on his work. We owe to him some forms of apparatus without which it would be impossible to do much of the chemical work in progress to-day.

Liebig's most important work was done at Giessen. As time passed on he got a better laboratory, and finally he was called to Munich, where everything possible was done for him by the king. He now had a fine laboratory, a fine, almost palatial, residence, unlimited funds, in short, ideal conditions, and what followed? Why, from that time to the end of his life — a period of twenty-one years — his contributions to chemistry amounted to very little. His best work had been done under the unfavorable conditions.

In a recent address, Lord Rayleigh, the distinguished English physicist, said he thought "it just possible that nowadays scientific work was made too easy, or, at all events, too mechanical, for the full advantage of it to be reaped, and that the scientific spirit and method were, perhaps, better cultivated by the less perfect appliances of the past." He stated that many of the great experimenters had "worked with exceedingly homely apparatus." Among those named by him in this connection was Clerk Maxwell, who had always got along with simple things, and yet was one of the greatest physicists of the last century.

Another great experimenter who achieved much with little was Hughes, "the father of many electrical inventions."

Lord Rayleigh called upon Hughes one night, and found him working at the microphone, which he had invented. He says, "Hughes had no apparatus at all. A few match boxes, a stick or two of sealing wax, some nails, and a single cell of a battery made up in a bedroom tumbler constituted the material of his invention."

The late Professor Rowland, of the Johns Hopkins University, had to a remarkable degree the power of making what he wanted out of what he found at hand. Some of the important pieces of apparatus with which he either carried out or started his investigations were apparently thrown together in the most haphazard way, yet the essential constituents were there. His early work was done without a well-equipped laboratory — some of it in a kitchen, and a poor kitchen at that. Like other great experimenters, he could help himself.

Examples could be multiplied without end, all going to show that many of the best thoughts of the world have had their origin in humble surroundings. Their birth has been attended by little pomp and ceremony. These examples,

if properly studied, show us something else. They show us that great results have often been reached in the course of investigations begun most modestly, without an idea as to where they would lead. The masters in science have not been afraid to attack what appeared to be small problems, but as their work advanced the small problems have become large.

When Dalton began his simple experiments on gases and liquids he had not a thought that he was laying anew the foundations of chemistry. His great thoughts came to him as his work went on. Scheele had no idea that his experiments would lead to the discovery of oxygen and chlorin. He did what his hands found to do, and he had the power to appreciate his results and to interpret them, although he never could have realized the importance of his fundamental discoveries. Even now we do not realize their full importance.

A good illustration of the way in which a simple observation may lead to important results is this:

In the early part of the last century, at a ball given at the Tuileries in Paris, the guests were much annoyed by something irritating in the air. The source of the trouble was found to be the wax candles. The matter was referred to the principal chemist of the day, who in turn intrusted it to his son-in-law, who happened to be Dumas, then quite a young man.

Dumas found the explanation. The wax used in making the candles had been bleached by chlorin. But the chlorin had not only bleached the wax, it had found its way into the wax, and when the candles burned it was given off in the form of a compound that was irritating to eyes and throat.

This led Dumas to study more thoroughly the effect of chlorin on wax, and results followed that practically revo-

lutionized the views of chemists and contributed very largely to the advancement of chemistry.

In this case, it will be noted, the circumstances that surrounded the birth of the discoveries in question were not humble. From a worldly point of view they were regal. But it is further to be noted that the splendid surroundings had nothing whatever to do with the discovery. It is safe to assume that there was not a person present at that now famous ball who could have thrown the least light on the cause of the discomfort. The genius of Dumas found its opportunity. The guests of royalty had coughed and wept to some purpose.

But enough. Only one thought in conclusion. It may be asked why, if so many discoveries have been made with simple things in simple surroundings, should so much be spent on scientific work? Times have changed. Many of the problems that in earlier times could be solved with simple things have been solved. The difficulties of scientific investigation are increasing. More and more refined apparatus is coming to be necessary. Although it is true that a considerable part of the money that is spent on laboratories could be saved, expensive apparatus is often required, and many profitable lines of investigation could not now be followed without large expenditures. Millions are now available for such work, and no doubt many millions more could be used to the advantage of the world.

AN ERA OF MECHANICAL TRIUMPHS[1]

BY ROBERT H. THURSTON

THE nineteenth century probably will always be remembered, however long the world may last and whatever may prove to be its future progress in mechanics and the useful arts, as having been the century in which the long dormant genius of invention was awakened into life and full activity. This century saw the grandest triumphs of every department of material growth and advancement. The steam engine, little known and hardly appreciated as a possible burden bearer for the race, has come to carry the whole weight, practically, of modern civilization. It does the work of a thousand millions of laborers, three or four times the working force of the world; it transports a thousand tons a thousand miles, in the modern steamship, at the cost of fifteen tons of fuel; it carries the whole commissary supply of the family of a citizen of New England from the cities of Chicago, Minneapolis, Kansas City, or St. Louis at a cost of about ten dollars annually; it consumes a pound or two of fuel and utilizes the dormant energy thus awakened in every direction in which its aid is desired, in the performance of the full day's work of an able-bodied man.

The electric current, formerly mysterious, awe-inspiring, and only destructive where its effects became visible, has been reduced to service, and not only now acts as a courier transmitting messages across continents and under oceans, or bringing friends a thousand miles apart ear to ear, but has become the right arm of the steam giant and applies

[1] By permission of "The Engineering Magazine."

the power of the engine to the performance of work miles from the prime motor, sets the locomotive aside, and drives the train with a thread of wire. Machinery has entered into every department of human labor, and has not only relieved the workman from labor, but enabled him to produce an enormously greater product of vastly greater excellence.

The practical outcome of this revolution of a century has been the promotion of the welfare and comfort of the whole world, the elevation of races to higher planes of life, the advancement, not only of the material interest of the world, but also the intellectual and the moral life of its people, With relief from the necessity of daily and incessant drudgery comes the power of devoting a part of life to thought, to self-improvement, to enjoyment of the comforts and of the luxuries, physical, intellectual, and moral, which the new life offers. It will be interesting to note what have been the material results of this era of mechanical triumph, in which all the powers of nature have been reduced to the service of man, and in which the "art preservative of all arts" and its instrument, the printing press, one of the most wonderful of the triumphs of invention, have given permanence and universal distribution to this extraordinary advancement.

As we look back over the single generation just ended, or back, we will say, to the beginning of the last half of the nineteenth century, it is easy to see that, as every economist has observed, this reduction of the forces of nature to service in the arts has, within the short period referred to, enormously increased the world's capacity for production in every field of industry. It has given the average citizen the means of securing an enormously increased proportion of the necessaries, of the comforts, and even of the luxuries of life, as they would have been

termed at the commencement of this period. Various writers estimate this gain at from thirty to fifty per cent more. At the prices to-day current, in many cases, the workman secures by a day's labor double the amount of food and clothing that he could have obtained then, and in many other cases he is able to procure what the wealthiest could not have obtained at any price a generation or two earlier. Costs of transportation are reduced both by reduction in costs of steamships and locomotives and by diminished costs of operation.

The consumption of iron and steel is one of the best gauges of progress and of the condition of a nation. The United States, now the greatest producer of the world, makes more than ten million tons a year, of which about one-half is made into steel, and consumes all this and still imports more from abroad. This is above three hundred pounds for every inhabitant, the largest consumption, in proportion to population, of any nation on the globe. This places us in the front rank among nations, thanks to Dudley and Cort, and Bessemer and Holley, who made all this possible by their inventions, and to men like Jones and Forsythe, who systematized and reduced to most perfect method the processes of the furnace and the mill, making the cost one-half what it was a few years ago, in fuel, and a small fraction, one-fifth, in dollars and cents.

Production of clothing has similarly increased in quantity and diminished in costs. According to Mr. Norcross, the increase in the boot and shoe business has been, in the last forty years, about four hundred per cent, consequent upon the application of the genius of the inventor and the skill of the mechanic to the construction of largely automatic machinery. No one goes barefoot to-day, except from choice. Only the wealthy wore shoes, habitually, a few generations ago. In Dakota the labor

of one man, reënforced by the power of horses and of steam, and supplemented by the inventions of McCormick and his fellows, the makers of the reaping machine, produces between five thousand and six thousand bushels of wheat; and this, according to Mr. Wells, is converted into a thousand barrels of flour by the labor of another man for the period of one year; while the labor of two more men deposits this flour on the dock at New York, and it is sent to Europe to compete in the market with the product of the cheapest labor and most productive soils of Africa and of India. In the times of Adam Smith, a century ago, ten persons made forty-eight thousand pins in a day. A hundred years later, seventy machines, with three men in attendance, aided by the brain work of some few hard-handed demigods, produced seven million five hundred thousand better pins.

The changes within the past century, which have been the changes, in the main, from semi-barbarism to enlightened civilization, and greater than in the preceding thousand years, comprise advances in every department of industry and the creation of many new arts. A century ago President Washington wore, at his second inauguration, woolen cloth costing five dollars per yard, made up at a woolen factory then recently established; while his family, like all others in the land, were clothed principally in homespun. Similar goods would probably now cost two dollars a yard, and the people are clothed in the product of the power loom, then unknown, and only invented two generations later.

The spinning wheel has gone with the wooden clock, the hand cards, the knitting needles, of our grandmothers. Exportation of cotton began in 1784; to-day we grow eight million bales a year, exporting a large fraction, and our woolen mills turn out five hundred million pounds of

cloth and other woolen products. A century ago, Great Britain produced but about seventy-five thousand tons of iron, and the United States about thirty thousand; to-day we see annual products of over a hundred times the larger quantity, and equal amounts in both countries. Steel was then hardly known; to-day we make several millions of tons, and at less cost per ton than was paid for the cast iron of those days. Wages of mechanics ranged from fifty to seventy-five cents per day, and unskilled labor twenty-five to thirty cents. But the workmen of that time paid from sixteen to twenty cents a pound for meats; eight dollars a barrel for flour; calico cost fifty to sixty cents a yard, broadcloth of ordinary quality three dollars, hose one dollar and a quarter a pair, and "Nankeen breeches" five dollars and a half.

Luxuries now considered necessaries of life then cost prohibitive prices, for the average citizen. Sugar, for example, cost fifteen to twenty or even twenty-five cents a pound. Salt cost fifty cents a bushel, unpurified and unground. Could the people of the eighteenth century have visited the World's Columbian Exposition in 1893, they would have discovered the machine-made clock and those greatest wonders of mechanism, the machine-made watches of Waltham and of Elgin; chronometers rated to insensible variations during a year of use; power looms making cloths in the most extraordinary variety of patterns, producing even pictures, landscapes, and portraits in most extraordinary perfection; knitting machines making garments to fit the form without seam; and cloths of the most wonderful elasticity and softness.

They would have been astonished by the cotton gin and its work, the carding machines for cotton and for wool, the mineral oils, the gas light, the electric light, pressed glass and machine-made bricks, machine-made shoes of

perfect form and splendid finish, and at a minute fraction of the prices of their time. Iron plows, the mowing machine, the reaping machine, the "self-binder," — cutting the grain, rolling it into bundles, tying it with strong cord, and depositing it in place for the loaders, who later carry it to the threshing machine, — steam-driven threshers, and numerous other "farmers' helps" would astound the agriculturist of the eighteenth century. A volume — a library, even — would hardly suffice to describe the wonders introduced by the inventors and mechanics of the nineteenth century.

In every department of human labor and production the work of the inventor and mechanic is seen, cheapening costs and increasing the product; giving a single man the powers of a hundred; relieving him from the heaviest burdens; bringing him food and clothing and every comfort in life from across the continents and over the oceans; developing for him new industries and diversifying the old; until he is become infinitely safer against the vicissitudes and fluctuations of the industrial tides than ever before.

The diversification of industries is, perhaps, the most obvious and effective of all the results of this progress of a century, and is the grandest of the triumphs of this mechanical age. It is this which gives employment to the steadily growing population, supplies to skill and talent special fields of work, relieves the lower class of laborers of that competitive pressure which otherwise is sure to destroy them by thousands, and gives to the world its opportunities and its progress.

The sewing machine has given employment to a thousand where one sang the "song of the shirt" before, and has introduced a myriad new and beautiful and inexpensive fabrics and garments where the richest formerly

could only obtain a limited number after long, patient, and killing toil on the part of the makers; and even the accelerating rotations of the fashions, promoted by invention and varied industries, aid in giving to the poor of the substance of the rich, and in equalizing for all the distribution of the best of the world's most useful and continually increasing variety of good things.

In a generation, the wealth of the civilized world has doubled, and mainly to the advantage of the poor and the less wealthy classes. Wages have doubled, and the purchasing power of the dollar has, in most directions and on the average, increased fifty per cent and more. Mr. Giffen asserts that the rich have become more numerous, the poor less numerous, and the intermediate classes are all much better cared for and richer than formerly. "The poor have had almost all the benefits of the great material advance of the last fifty years." This, as that writer remarks, is not so much an improvement as "a revolution of the most remarkable description." Where, as in cotton spinning, a man can now do, with the aid of machinery, four or five times the work that he could have done a half century ago, and can obtain twice the wage for his shorter day's labor, it is obvious that the world must, on the whole, have gained enormously in wealth, comfort, and happiness. And this has come largely of this direct stimulation of production due to the introduction of modern inventions and machinery, and largely, also, of that diversification of industries which the resulting increase of wealth and available time has rendered possible.

The innumerable wants of the wealthy, the numberless comforts of the well to do, and the continually growing list of what are now considered necessaries of life for the poor, promise to make the further diversification of the

industries and the widening of the new fields, in which time and thought and labor have their applications, a permanent feature of human life henceforward. And this prospective increase and continual improvement will unquestionably inure, in the future as in the past, mainly to the advantage of the workers themselves. Already, as shown by Mr. Edward Atkinson, ninety per cent of the people are at cnce producers and consumers, and these classes are, "decade by decade, securing to their own use and enjoyment an increasing share in a steadily increasing product." As has been so well shown by Mr. David A. Wells, "the time has come when the population of the world commands the means of a comfortable subsistence in a greater degree and with less effort than ever before; and what we may reasonably expect to see at no very remote period is the dawn of the day when human poverty will mean, more distinctly than ever before, physical disability, mental incapacity, or unpardonable viciousness or laziness."

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